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ARMSTRONG LABORATORY

# EVALUATION OF THE EFFECTS OF VISUALLY COUPLED SYSTEMS ON THE BIODYNAMIC RESPONSE TO SIMULATED EJECTION ACCELERATIONS



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## NOTICE



## TECHNICAL REVIEW AND APPROVAL

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Thomas J Moore

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The deployment of helmet-mounted visually coupled systems such as night vision devices and helmet mounted displays is being investigated to assist in demanding day and nighttime aircraft operations. In response to this, six prototype helmet systems and two baseline helmets were subjected to simulated ejection environments (+Gz impact accelerations) using human and manikin subjects and a vertical deceleration tower to determine the head/neck injury potential. Injury potential was a concern due to increased head supported weight and altered center-of-gravity provided by helmet mounted visually coupled systems. Analysis of the test results indicates that the six prototype helmets will generate neck loads in an ACES II ejection that are potentially no greater risk than baseline helmets in a B-52 ejection environment. The prototype helmets were potentially a greater risk than the baseline helmets in a B-52 ejection environment.

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# PREFACE

This test and evaluation effort was accomplished under a memorandum of agreement with the Helmet Mounted Systems Technology Advanced Development Program Office (HMST ADPO) under the Crew Systems Directorate. The program managers for the HMST office were Capt Karen Cooper and Mr Scott Hall.

The test program was planned and conducted by members of the Escape and Impact Protection Branch, Biodynamics and Biocommunications Division of the Armstrong Laboratory (AL/CFBE). This report describes the results of impact tests with manikins to evaluate the injury potential of several prototype helmet mounted visually coupled systems in simulated ejection environments (+Gz accelerations).

The test facilities, data collection, and data processing equipment were operated by the Scientific Services Division of DynCorp under Air Force Contract number F33615-86-C-0531. Mr Marshall Miller was the engineering supervisor. The outstanding support of Mr Ron Riddle, Mr Jim Mullins, Mr Ben Mullenix, Mr Mike Clark, Mr Walter Scherer, Mr Stephen Mosher, and Mr Bob Flannery deserves special recognition due to the logistics and technical nature of the test program.

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# INTRODUCTION

## Overview and Objectives

An experimental research effort was conducted to measure the effects of several prototype visually coupled systems (VCS) on the human head and neck response to a simulated ejection pulse. The effort was conducted in two phases with the first phase testing an advanced dynamic manikin's (ADAM) response with various prototype VCS, and the second phase testing volunteer human subjects' responses with the same prototype systems.

The primary objective was to define the human head and neck dynamic response parameters for the development of head-mounted weight and center-of-gravity criteria. The criteria will be used to evaluate the effects of present and future helmets and advanced helmet-mounted visually coupled systems on ejection biodynamics. A secondary objective was to compare and correlate the ADAM responses to human subjects. To complete these objectives, human and manikin head and neck responses to whole-body simulated ejection impact accelerations with various prototype helmet-mounted VCS were measured and analyzed.

## Background and Relevance

The mission profiles of some current military aircraft equipped with ejection seats are now being expanded for more demanding day and nighttime operations. To help overcome adverse flight conditions and improve pilot performance, the deployment of helmet-mounted visually coupled systems such as night vision devices and helmet mounted displays are being explored. During these demanding operations, the possibility exists for emergency escape by high-airspeed, low-altitude ejection. There has not yet been an incident requiring emergency escape by ejection while operating the helmet mounted systems; however, if the present systems were used during emergency escape, unacceptably high rates for major injuries and fatalities could occur. This would be due to the increased mass and altered weight distribution that the systems add to the head, and their effect on the dynamic response of the ejectee's head and neck.

Minimal quantitative information is available regarding +Gz human neck tolerance with the addition of these external head mounted devices; moreover, there is also a lack of USAF criteria regarding maximum allowable head-supported weight and shifted center-of-gravity. Melvin (1979) reviewed mechanisms of injury and human cadaver tolerance levels. Settecerri, Privitzer, and Beecher (1987) studied the mass properties and inertial loading effects of head encumbering

devices utilizing anthropomorphic manikin heads. Following recent studies in -Gx human dynamic response (Muzzy, 1986), the Naval Biodynamic Laboratory subsequently proposed guidelines for safe human experimental exposure to impact acceleration (Naval Biodynamic Laboratory Impact Acceleration Guidelines, 1989). Limits (sled acceleration of 12.5 +Gz for 90 milliseconds with an end sled stroke velocity of 12 meters/second) were recommended for torso restrained, unhelmeted volunteers having the freely moving head and neck as the anatomical segments at risk. However, little work has been done to quantify the human dynamic head and neck response following +Gz impact exposure simulating the ejection environment. This experimental effort was directed towards reducing any increased morbidity and mortality to ejection crewmembers due to helmet-mounted visually coupled systems and other head encumbering devices.

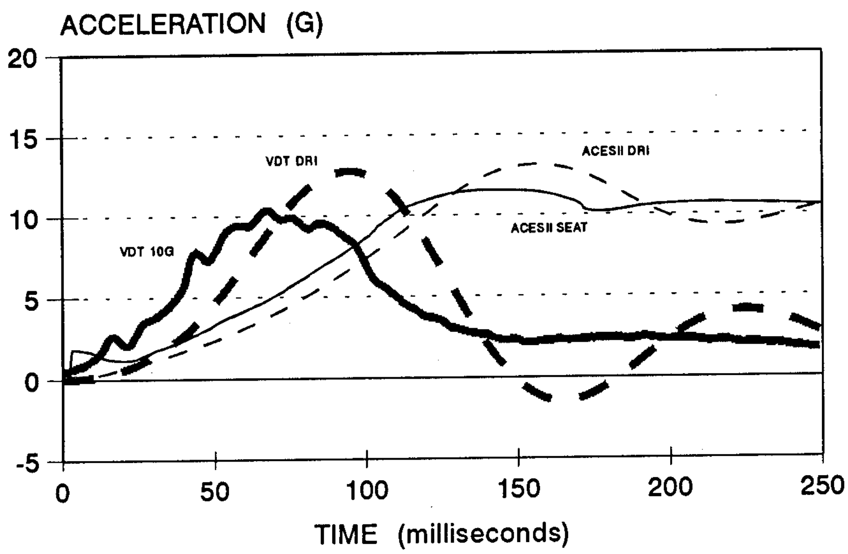
## METHODS

The simulated ejection impulse environment was provided using a series of short-duration, +Gz impact accelerations using the AL/CFBE Vertical Deceleration Tower (See Figure 1 in Appendix A). The tower is constructed of two vertical guide rails upon which a test carriage is positioned. The carriage is raised to a pre-determined height and then allowed to free-fall into a water reservoir. The height of the carriage and the shape of a piston (on the bottom of the carriage) that impacts the water, control the pulse shape of the input acceleration. A generic seat was mounted on the carriage assembly in an upright position to provide a +Gz input acceleration to the subject. Tests were conducted without a seat cushion on the flat seat pan of the generic seat. The seat back angle was positioned 0° vertical. The restraint harness was a standard USAF double shoulder strap and lap belt configuration. The headrest was in line with the seatback for the manikin tests but was 1 inch behind the seatback for the human subject tests. This headrest position allowed the subject to have his eyes forward without head rotation, and to have his cervical vertebra aligned parallel with the seatback while wearing the prototype systems. Collected data included carriage acceleration and velocity, seat acceleration, ADAM neck and spine loads using Denton six-axis load cells, head and chest accelerations, and seat and restraint forces. For more detailed information on the test setup or the instrumentation system, please refer to Appendix A.

The Armstrong Laboratory Human Use Review Committee approved testing of the human subjects with the prototype helmet systems at a 10 G impact acceleration level with corresponding maximum velocity change of 30 feet/second. This was also within guidelines defined by the Crew Systems Directorate's Generic Impact Acceleration Protocol (GIAP). ADAM was subjected to impact from 6 to 20 G to provide a broader range of responses, and for comparison to current and previously collected human response data. The 10 G impact acceleration on the VDT is a simulation of the ACES II ejection because both produce an average Dynamic Response Index (DRI), a spinal injury predictor, of approximately 12.5. The 15 G impact acceleration on the VDT is a simulation of a B-52 ejection profile with a DRI of approximately 19. See Figures 1 and 2 for comparison of the ACES II seat and B-52 ejection profile to the acceleration pulse developed by the VDT.

This research program tested and compared prototype VCS helmets and two baseline helmets. The baseline systems were the USAF HGU-26/P and the HGU-55/P flight helmets with a MBU-12/P mask. The prototype helmet systems were provided

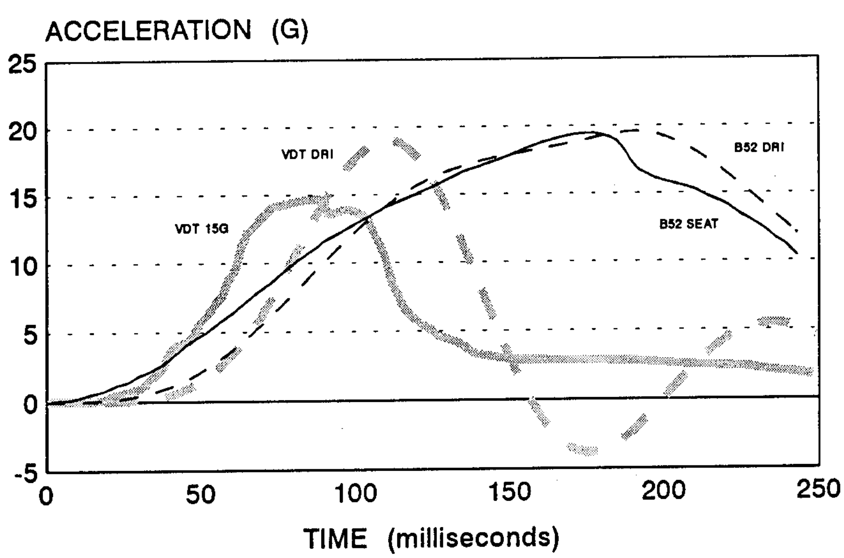
## ACESII EJECTION PROFILE
### ACESII SEAT ACCEL. vs VDT FACILITY ACCEL.




VDT - VERTICAL DECELERATION TOWER

FIGURE 1

## B-52 SEAT EJECTION PROFILE
### B-52 SEAT ACCEL. vs VDT FACILITY ACCEL.




VDT - VERTICAL DECELERATION TOWER

FIGURE 2

by three vendors each of which supplied two prototype systems. One system was a night vision only system, and the second was a night vision device and helmet mounted display combination. This made for a total of six prototype systems and eight overall helmets (including baselines) to be tested. The three vendors in alphabetical order are GEC Avionics, Honeywell, and Kaiser. Each system when discussed will be referred to the vendor by first letter only and as to type of system by NVG for night vision device helmet systems, and by HMD for the night vision device/helmet mounted display helmet systems.

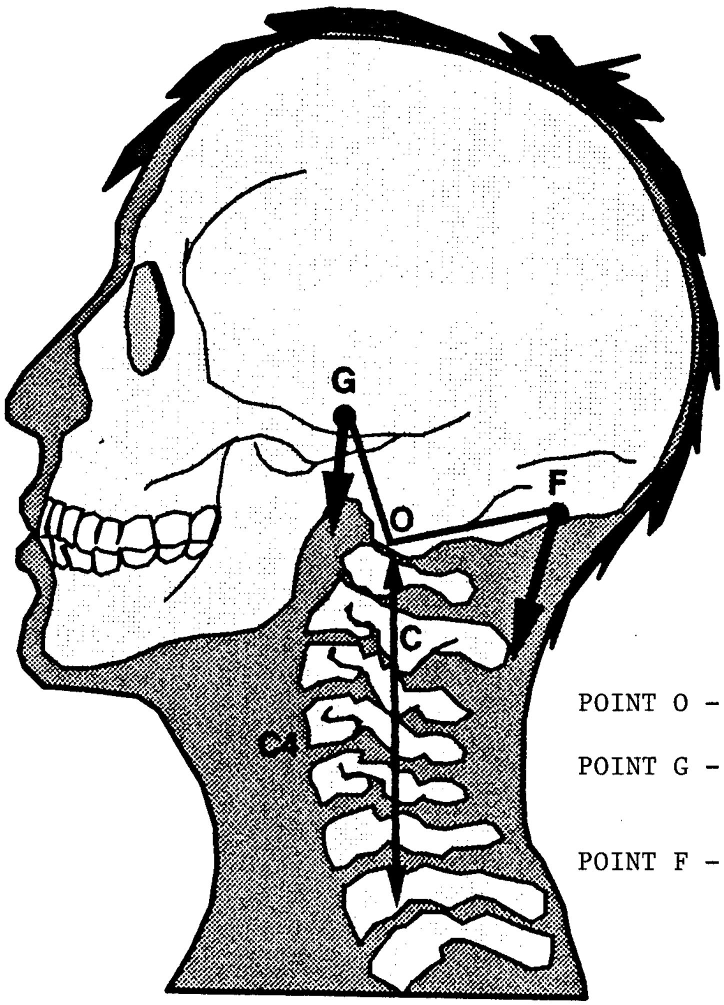
The experiment was conducted in two phases. In the first phase, ADAM was exposed to impact accelerations (6 through 20 G) in a progressive order with each helmet (prototype and baseline). The 20 G tests were conducted to test structural integrity. The manikin was exposed from between three to five times per impact level with each helmet. In the second phase, the human subjects were also exposed to all eight helmets but only at 10 G. This report will primarily discuss results from the first phase.

## RESULTS

A comparative type analysis was used to analyze the effects of the prototype VCS on the biodynamic response during ejection. The comparison was between the I-NIGHTS helmet's response and the baseline helmet's response . The I-NIGHTS response was also compared to neck strength as found in the literature. For the comparisons, the primary response parameters were the z-axis compressive load at the occipital condyle, the x-axis shear load at the occipital condyle, and the torque or bending response at the occipital condyle. The occipital condyle is the cervical joint where the skull attaches to the first neck vertebrae (Figure 3).

To understand the potential problems that the prototype helmets could give a pilot beyond those of the baseline helmets, the inertial properties of the systems must first be analyzed. Inertial properties include weight, center-of-gravity (Cg), and moment of inertia or mass distribution. Table 1 shows the weight of each system, the system with a MBU-12/P mask, and the Cg of the system in combination with the large ADAM head and the mask. The Cg is shown with the ADAM head for relative comparison purposes. The moment of inertia data is not shown because the design of the prototypes is based on a baseline helmet platform, and the gross shape of the helmet will be limited by the headroom in the cockpit. The inertial property data shows the prototype systems are approximately 2 to 3.5 pounds heavier than the baseline helmets with a mask. In addition, the location of the optics of the visually coupled devices is forward of the baseline helmet/head combination by approximately 0.5 to 1.0 inches. From this data it is apparent the effects of the increased weight and shifted center-of-gravity must be considered in the design and performance analysis of VCS helmets.

Since the analysis of the data is of a comparative nature, this report will focus on the results of the manikin tests and their indications. The human test data, and its correlation with the manikin data, will be discussed in future reports; however, a few brief words shall be mentioned here. Human neck loading (z-axis compression, x-axis shear, and torque) was estimated using the measured linear and angular accelerations of the subjects' heads. Preliminary analysis indicates that the Hybrid III neck found in the ADAM reasonable predicts the compressive and shear loading in the human neck. The torque measured on the ADAM was approximately 50% less than that estimated for the human subjects. Further analysis will include continued correlation of the human data to ADAM, and correlation of




POINT O - OCCIPITAL CONDYLES

POINT G - CENTER OF GRAVITY OF HEAD

POINT F - NECK MUSCLES BALANCING FORWARD ROTATION OF HEAD

FIGURE 3. PHYSIOLOGY OF NECK LOADING

**Table 1. Various Helmet and Helmet-Mounted Visually Coupled System Inertial Properties.**

| SYSTEM | WEIGHT (LB) | WEIGHT W/MASK (LB) | CENTER OF GRAVITY (IN) | | |
|---|---|---|---|---|---|
| | | | X | Y | Z |
| MALE HUMAN HEAD | 9.47 | | -0.28 | -0.02 | 1.23 |
| LARGE ADAM HEAD | 8.93 | | -0.32 | -0.03 | 1.01 |
| HGU-26/P | 2.81 | 3.61 | -0.26 | 0.05 | 0.82 |
| HGU-55/P | 2.43 | 3.23 | -0.14 | 0.13 | 0.92 |
| 55/P+EAGLE EYE NVG | 3.96 | 4.76 | 0.14 | -0.04 | 0.70 |
| I-NIGHTS G NVG | 4.54 | 5.34 | 0.25 | -0.03 | 1.09 |
| I-NIGHTS G NVG/HMD | 5.64 | 6.42 | 0.32 | 0.00 | 1.31 |
| I-NIGHTS H NVG | 5.16 | 5.96 | 0.13 | 0.06 | 0.90 |
| I-NIGHTS H NVG/HMD | 5.71 | 6.51 | 0.25 | -0.08 | 0.69 |
| I-NIGHTS K NVG | 4.81 | 5.62 | 0.56 | 0.11 | 1.39 |
| I-NIGHTS K NVG/HMD | 5.84 | 6.64 | 0.41 | 0.03 | 1.39 |

*Notes:*

(1) Mask used for weight calculations is MBU-12/P.
(2) All center of gravity data is relative to ADAM anatomical axis system.
(3) Helmet center of gravities are combined with an ADAM headform.

both manikin and human data to the inertial property data. These correlations will be the first step in the development of USAF standards on maximum head mounted weight and Cg shift.

Current analysis of the ADAM data is shown in Figures 4 through 9. All ADAM data has an average standard deviation of approximately 5% of the response. Each figure is a bar graph showing the prototype helmets responses as compared to a baseline helmet response at each tested acceleration level. Figures 4, 6, and 8 are of the prototype night vision device helmet systems and one of the baseline systems (HGU-55/P). It is shown that each of the three biodynamic responses (compression, shear, torque) increases with the applied input acceleration for each helmet. It is also shown that at each acceleration level the prototype helmets have greater responses than the baseline helmet. Interestingly, above 10 G the heaviest helmet, the Honeywell NVG system, has a decreasing compressive neck load compared to the other helmets. This apparent anomaly can be explained by noticing that the Honeywell system has greater shear and torque values than the other helmets indicating that the Honeywell system is off-loading its inertial response from the z-axis into the x-axis and the torque around the y-axis.

Figures 5, 7, and 9 are the ADAM results for the helmet mounted display systems and the HGU-55/P baseline helmet. Again the results are presented at each acceleration level for each of the three biodynamic parameters. As before the data increases with increasing input acceleration level for each biodynamic parameter. The heavier prototype systems (compared to baseline) generated higher compressive and shear loads but equal-to or less-than torque values, especially at the higher input accelerations.

# I-NIGHTS TEST PROGRAM

ADAM Z-AXIS NECK LOAD vs IMPACT ACCELERATION

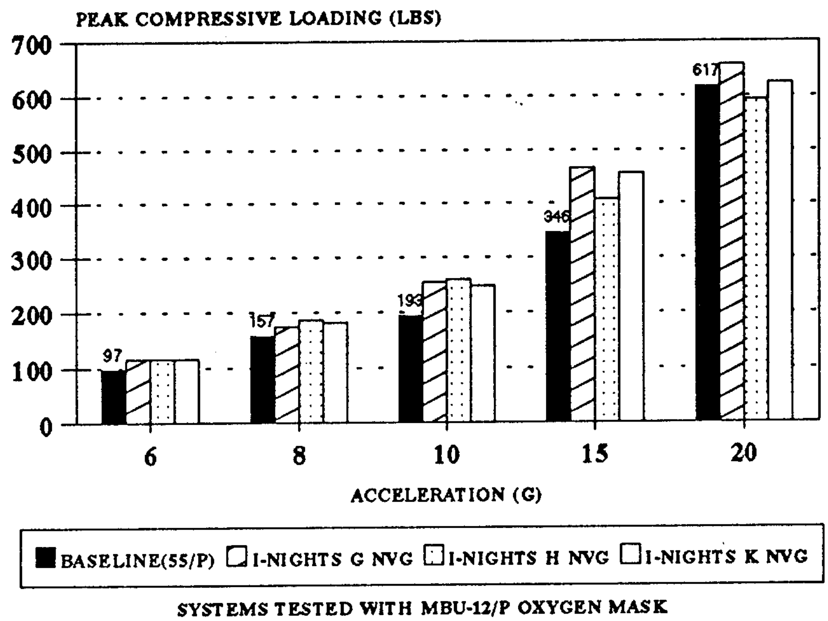



FIGURE 4

# I-NIGHTS TEST PROGRAM

ADAM Z-AXIS NECK LOAD vs IMPACT ACCELERATION

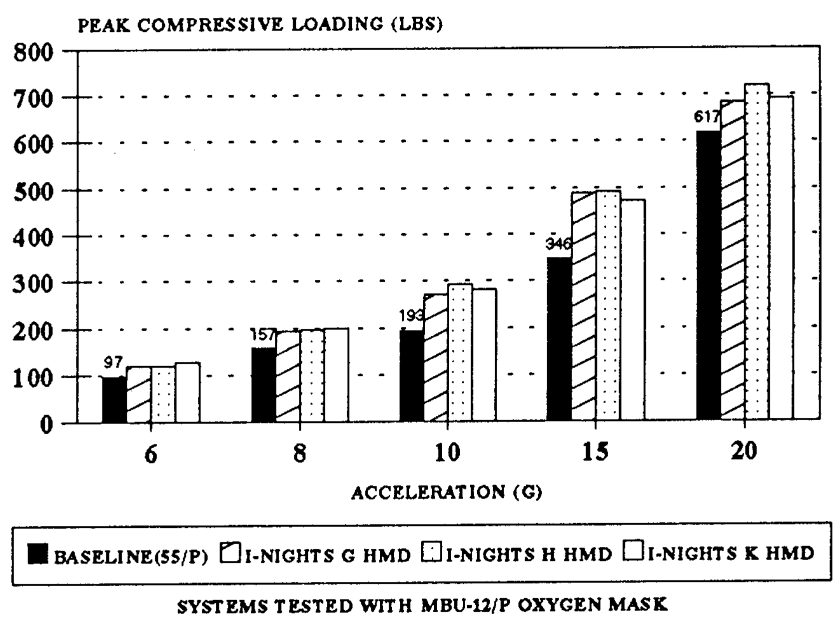



FIGURE 5

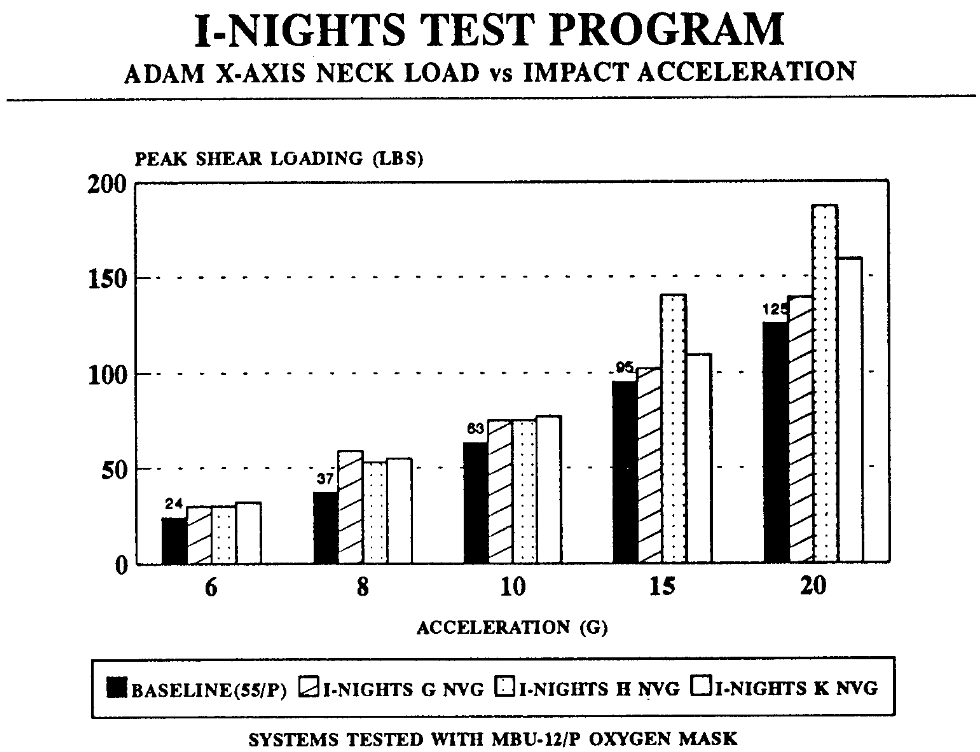



FIGURE 6

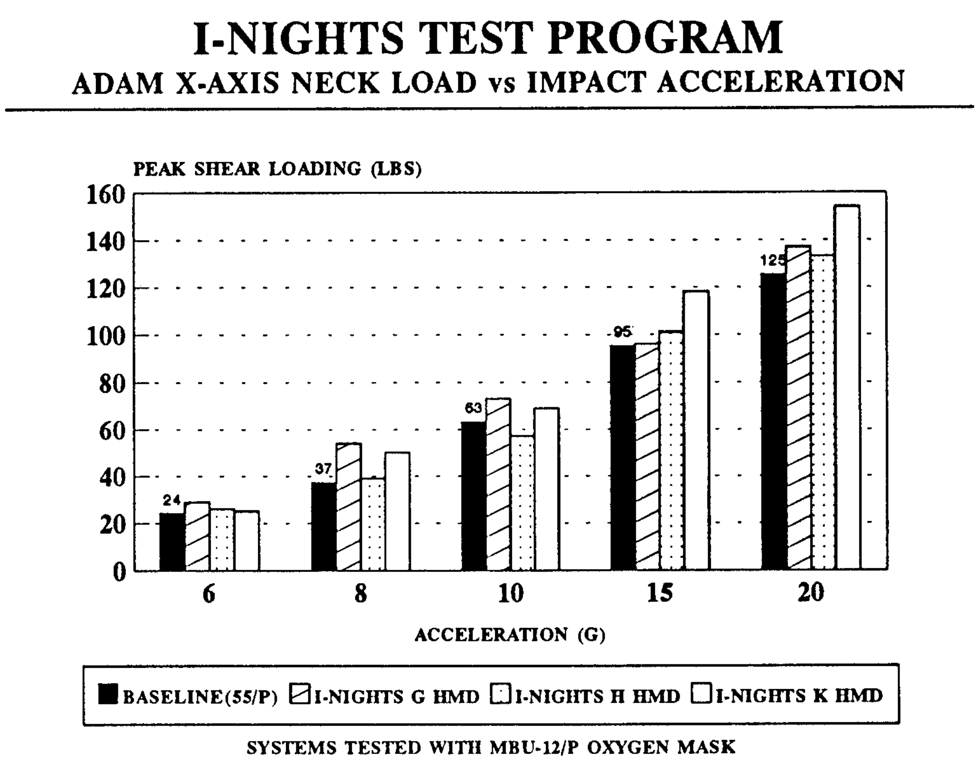
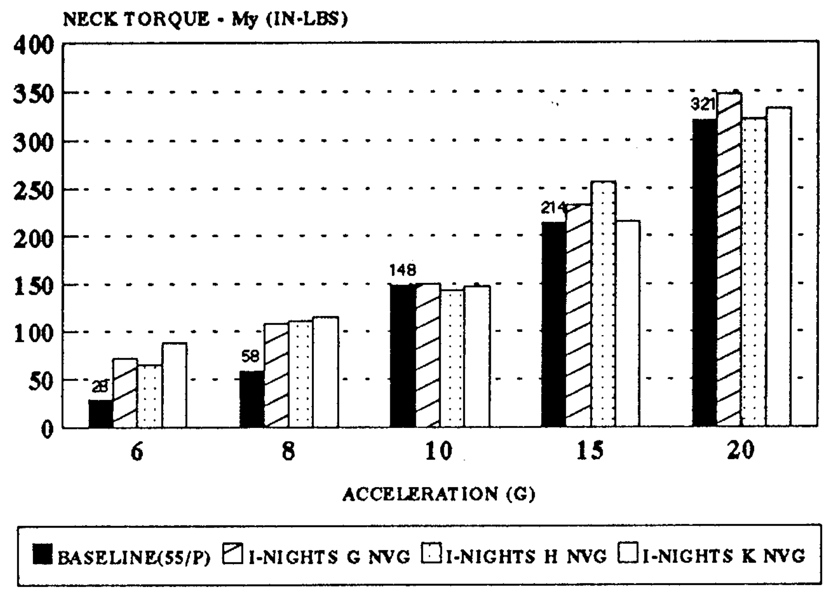



FIGURE 7

# I-NIGHTS TEST PROGRAM

## ADAM NECK BENDING RESPONSE vs IMPACT ACCELERATION

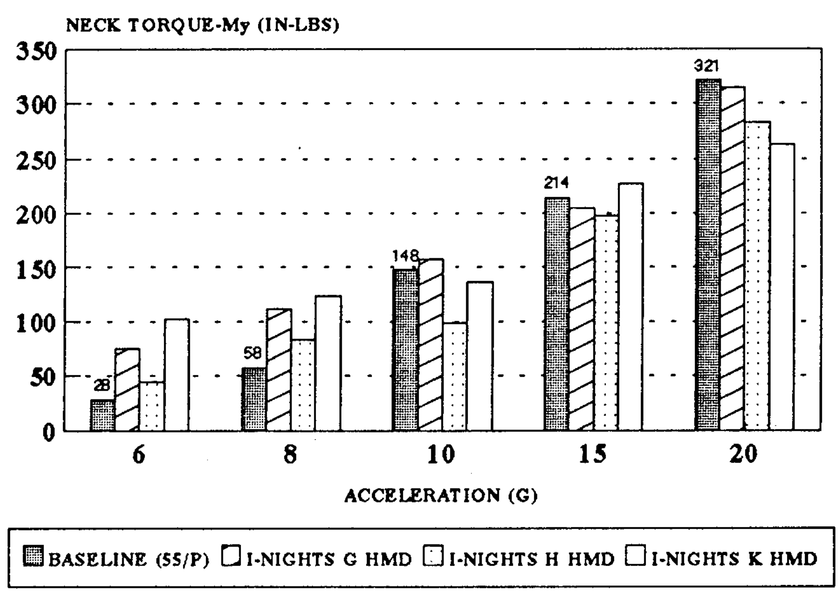



SYSTEMS TESTED WITH MBU-12/P OXYGEN MASK

FIGURE 8

# I-NIGHTS TEST PROGRAM

## ADAM NECK BENDING RESPONSE vs IMPACT ACCELERATION




SYSTEMS TESTED WITH MBU-12/P OXYGEN MASK

FIGURE 9

# DISCUSSION

The concern about the potential for neck injury during ejection from an aircraft was addressed by an 1984 AGARD working group. Their findings indicated that non-ejection, high maneuvering environments and emergency ejection environments produced cervical fractures with current USAF helmets. The introduction of night vision devices, helmet mounted sighting and display systems, or a combination of both can be expected to increase the risk of cervical injury to the aircrew because of the increased weight and altered center-of-gravity. However, there exists very little information in the literature <u>defining</u> the maximum allowable mass on the head or maximum allowable shift in the combined head/helmet center-of-gravity in order to reduce the risk of neck injury.

There are no <u>quantitative</u> methods for prediction of cervical vertebral fracture risk similar to that for thoracic-lumbar vertebrae by calculating the Dynamic Response Index (DRI) for proposed test conditions (Brinkley and Shaffer, 1971). Literature reviews and research have shown that acceleration levels of 20-21 Gs in the z-axis are routinely tolerated provided there is good body positioning (Henzel, 1967; Snyder, 1970). An occurrence of end-plate fractures of T-4 and T-5 at +10 Gz with a standard helmet (HGU-26/P) was due to improper body positioning just prior to impact.

U.S. Naval operational experience from 1949 to 1981 suggest a multitude of "ejection associated" factors (pre-ejection aircraft maneuver, poor positioning of the body, ejection catapult forces too high, windblast acting upon the ejectee's helmet, post-separation collisions of man and seat, parachute opening shock, ground contact, and rescue attempts) have resulted in an overall rate of approximately 7% for moderate "ejection associated" neck injuries and approximately 1% for severe neck injuries (Guill, 1983).

In a review of USAF aircraft accident data from 1978 to 1988 (Taylor, 1990), analysis focused primarily on head and neck injuries during ejection where the aircrew-member was known to be wearing either HGU-26/P or HGU-55/P flight helmets. The accidents which involved injury to the cervical spine showed approximately a 4% chance of occurrence, with half of the injuries being fatal.

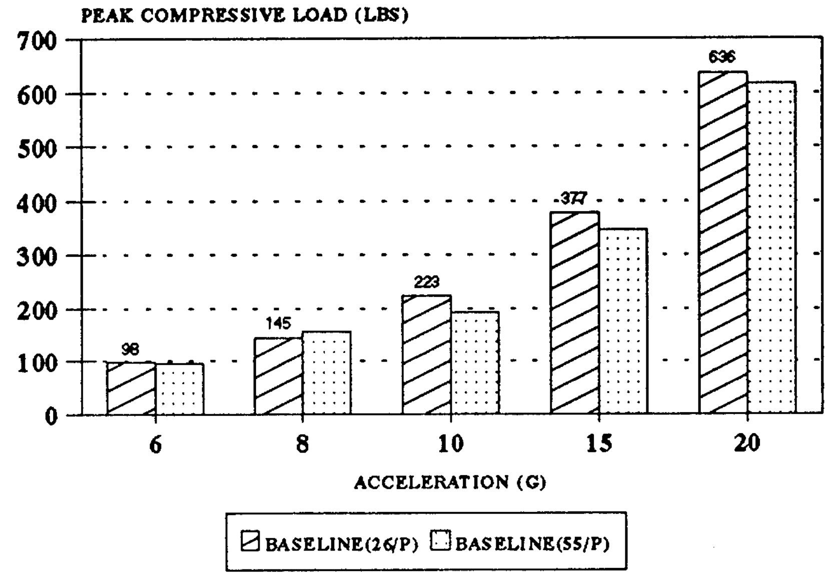
There is also very limited data in the literature indicating the strength and tolerance of the human neck in a dynamic environment. Estimates have been made using analytical models, operational accident data, and experimental impact data using human subjects and cadavers.

In a pioneering study, Mertz and Patrick subjected human volunteer subjects to static and dynamic environments producing non-injurious head and neck responses. Cadavers were used to extend the analysis into the injury region. Based on testing in the -Gx direction, the following injury threshold values (maximum responses <u>without</u> producing ligament or bone damage at the occipital condyle) were estimated for the neck in flexion: (1) Moment (My) of approximately 1700 in-lbs, (2) Shear load of approximately 450 lbs, and (3) compression load of approximately 400 lbs.

To determine the safety of the prototype I-NIGHTS helmets in an ejection, the limited injury and tolerance data requires a relative comparison analysis. The two different ejection profiles of main interest were the ACES II and the B-52 ejection seat profiles. The relative comparison for the prototype helmet systems in an ACES II ejection environment will be against the biodynamic data generated by the HGU-26/P baseline helmet in a B-52 ejection environment. The HGU-26/P helmet data can be found in Figures 10 through 12 with the HGU-55/P baseline helmet. As shown, there is little difference between the two baseline helmets except at the lower G levels for shear and torque loading where the greater x-axis Cg shift of the 26/P helmet takes effect. With a peak compressive loading of approximately 380 pounds at 15 G, the 26/P helmet is greater than either prototype (night vision or helmet display) helmet system at the 10 G impact level (See Figure 13). This indicates that the prototype systems could potentially generate no greater risk of compression injury than that produced by the 26/P baseline helmet. The same conclusion can also be reached for the shear and torque loading.

The second relative comparison analysis is for the B-52 ejection. At 15 G, all the prototype systems generate biodynamic responses greater than the 26/P baseline helmet; therefore, the comparison was then made to the injury threshold values determined by Mertz and Patrick. This comparison is conditional and is based on the assumption that the ADAM neck responses are representative of human responses under the same biodynamic conditions. This is currently being investigated and presently (based on limited data), it will be assumed that the ADAM neck did mimic the human neck response. This is in Figure 13 where a comparison was made between human and manikin z-axis neck loading (occipital condyle) at the 10 G acceleration profile. As stated previously, human data was estimated using measured head accelerations. The manikin data closely approximates the human response in a helmet weight range of 3.5 to 7.0 pounds at the 10 G acceleration level; therefore, it was assumed this relationship will also be held at the 15 G level. Under this assumption, the prototype helmets

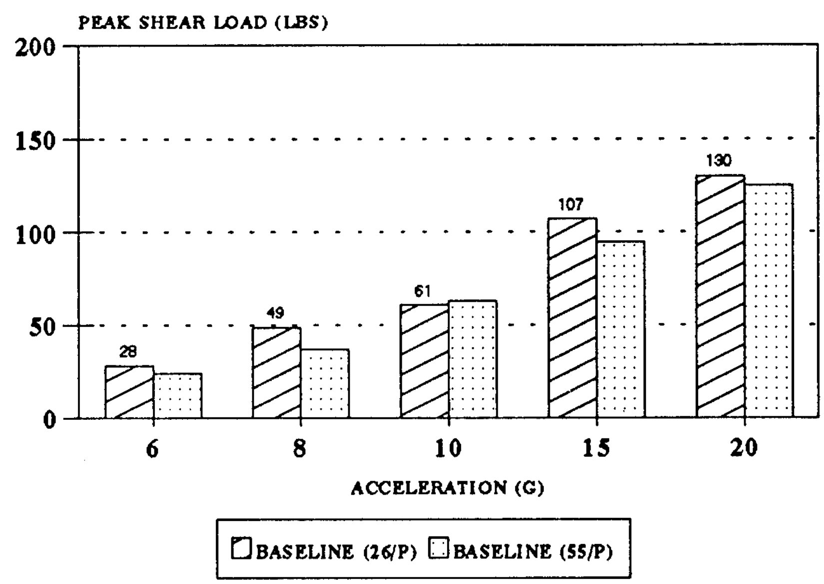
# I-NIGHTS TEST PROGRAM
## ADAM Z-AXIS NECK LOAD vs IMPACT ACCELERATION




SYSTEMS TESTED WITH MBU-12/P OXYGEN MASK

FIGURE 10

# I-NIGHTS TEST PROGRAM
## ADAM X-AXIS NECK LOAD vs IMPACT ACCELERATION

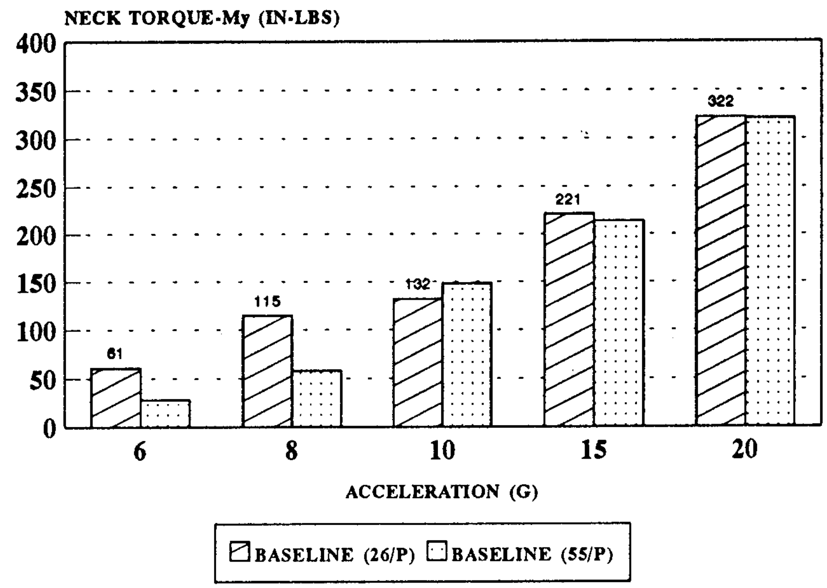



SYSTEMS TESTED WITH MBU-12/P OXYGEN MASK

FIGURE 11

# I-NIGHTS TEST PROGRAM

## ADAM NECK BENDING RESPONSE vs IMPACT ACCELERATION

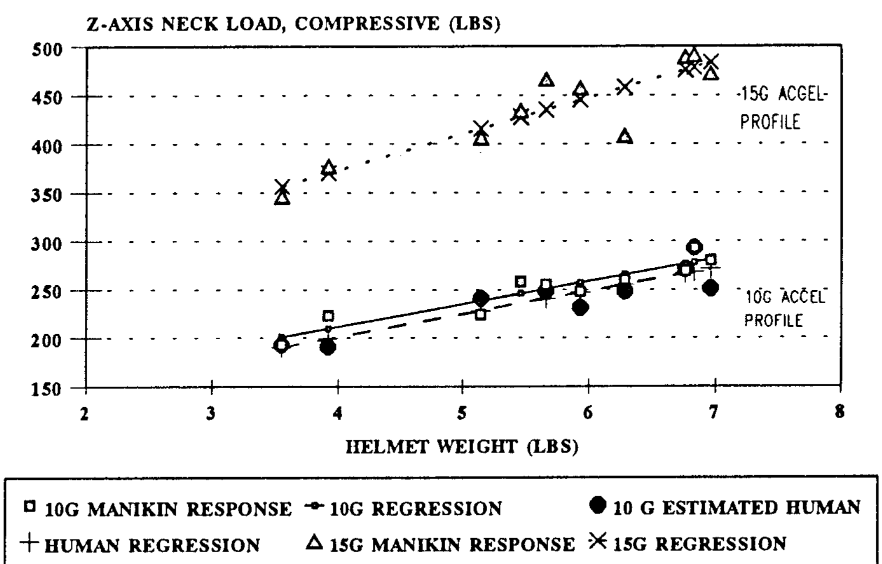



SYSTEMS TESTED WITH MBU-12/P OXYGEN MASK

FIGURE 12

# HELMET NECK LOADING

## Z-AXIS NECK LOAD vs HELMET WEIGHT

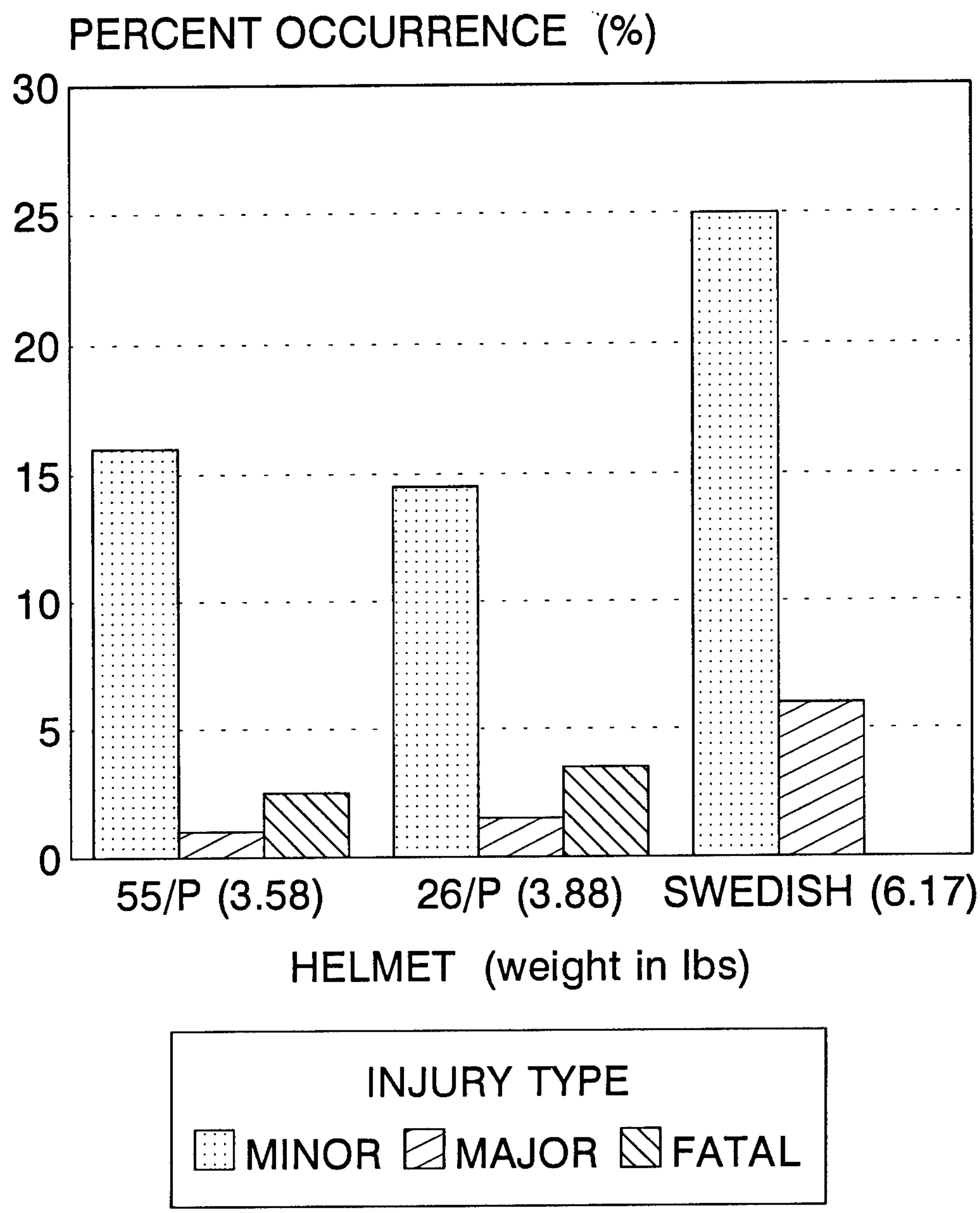



10G ACCEL APPROX. ACESII EJECTION PROFILE
15G ACCEL APPROX. B-52 EJECTION PROFILE

FIGURE 13

(night vision and helmet display) were well below the shear and torque thresholds (Mertz and Patrick), but exceeded the compression neck load threshold value of 400 pounds. At this point, the analysis dictates that none of the prototype helmets are safe for a B-52 ejection. Moreover, recent data on a 6.2 pound Swedish (Risk Assessment Working Group, 1990) flight helmet indicates a comparable fatal and major neck injuries (spinal impingement, fractures, disc ruptures) to the USAF baseline (55/P and 26/P) helmets, but a 25% rate of minor neck injuries (soft tissue soreness, neck strains). The Swedish ejection environment averages DRI values of approximately 21, greater than the B-52. Refer to Figure 14 for a break down of these statistics. If these injury rates are considered acceptable, then the night vision device prototype helmet systems (because of similar weight) in a B-52 ejection could be considered to have no greater risk than the Swedish helmet.

# EJECTION RELATED NECK INJURIES




HGU-55/P DATA BASED ON 226 EJECTIONS
HGU-26/P DATA BASED ON 254 EJECTIONS
SWEDISH HELMET DATA BASED ON 92 EJECTIONS

FIGURE 14

## CONCLUSIONS

The I-NIGHTS prototype helmet systems (all) will generate neck loads in an ACES II ejection that are potentially <u>no greater</u> risk than the neck loads generated by a HGU-26/P flight helmet in a B-52 ejection environment. The I-NIGHTS prototype helmet systems (all) will generate neck loads in a B-52 ejection environment that are potentially <u>a greater</u> risk than the neck loads generated by a HGU-26/P flight helmet in the same environment. The I-NIGHTS prototype helmet systems (night vision device only) will generate neck loads in a B-52 ejection that are potentially <u>no greater</u> risk than the 6.2 lb Swedish helmet.

It must be stated that these results are based on the responses of a manikin that has not been fully validated to simulate human responses; however, it is the best method available to test prototype equipment or safety systems before controlled human testing is conducted. As mentioned previously, data is currently being analyzed to correlated manikin and human responses with various helmet systems as well as to correlate the helmet inertial properties with the human and manikin biodynamic responses.

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# TEST CONFIGURATION AND DATA ACQUISITION SYSTEM FOR THE EVALUATION OF THE EFFECTS OF VISUALLY COUPLED SYSTEMS ON HUMAN RESPONSE DURING +Gz IMPACT ACCELERATIONS (VCSI STUDY) TEST PROGRAM

Prepared under
Contract F33615-91-C-0531

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INTRODUCTION

This report was prepared by DynCorp for the Armstrong Laboratory (AL/CFBE) under Air Force Contract F33615-91-C-0531.

The information provided herein describes the test facility, seat fixture, restraint configuration, test subjects, data acquisition, instrumentation procedures and the test configurations that were used in The Evaluation of the Effects of Visually Coupled Systems on Human Response During +Gz Impact Accelerations (VCSI Study) Test Program. Three hundred sixty-seven tests were conducted from July 1990 through April 1991 on the Vertical Deceleration Tower Test Facility.

1. TEST FACILITY

The AL/CFBE Vertical Deceleration Tower, as shown in Figure A-1, was used for all of the tests.

The facility consists of a 60 foot vertical steel tower which supports a guide rail system, an impact carriage supporting a plunger, a hydraulic deceleration device and a test control and safety system. The impact carriage can be raised to a maximum height of 42 feet prior to release. After release, the carriage free falls until the plunger, attached to the undercarriage, enters a water filled cylinder mounted at the base of the tower. The deceleration profile produced as the plunger displaces the water in the cylinder is determined by the free fall distance, the carriage and test specimen mass, the shape of the plunger and the size of the cylinder orifice. A rubber bumper is used to absorb the final impact as the carriage stops. For these tests, plunger number 102 was mounted under the carriage. Drop height varied depending on the test cell requirements which ranged from 5'6" to 28'8-1/2".

2. SEAT FIXTURE

The VIP seat fixture, as shown in Figure A-2, was used for all of the tests. The seat was designed to withstand vertical impact accelerations up to 50 G. Its adjustable seat back and seat pan were not adjusted during this study as all of the tests were run at the 0 degree seat back angle. The headrest was adjustable and capable of being mounted 2 and 3 inches forward of the seat back. When positioned in the seat, the subject's upper legs were bent 90 degrees outward to a horizontal position with his lower legs bent 90 degrees downward to a vertical position. The subject was secured in the seat with a conventional two-strap shoulder harness and lap belt. The lap belt and shoulder strap were preloaded to 20 ±5 pounds as required in the test plan.

Each of the subject's legs were restrained by a strap that encircled the subject's ankle and was attached to the carriage. Another strap crossed the subject's thighs and attached to the seat pan posterior to the knees.

The subject's hands were placed under the thigh restraint. These restraints are illustrated by Figure A-3.

## 3. TEST SUBJECTS

Both manikins and human test subjects were used during this test program.

A 95th percentile Alderson manikin, designated VIP-95, was used for structural and equipment proof tests.

One ADAM manikin representative of the "large" flying population was also used during this test program.

## 4. TEST CONFIGURATIONS

Several combinations of Night Vision Device/Helmet Mounted Display Systems were used as follows:

1) HGU-55/P helmet/MBU-12/P mask/no Night Vision Devices
2) HGU-26/P helmet/MBU-5/P mask/no Night Vision Devices
3) 3G helmet/MBU-12/P mask/Night Vision Device/no Helmet Mounted Display
4) 3G helmet/MBU-12/P mask/Night Vision Device/Helmet Mounted Display
5) 3H helmet/MBU-12/P mask/Night Vision Device/no Helmet Mounted Display
6) 3H helmet/MBU-12/P mask/Night Vision Device/Helmet Mounted Display
7) 3K helmet/MBU-12/P mask/Night Vision Device/no Helmet Mounted Display
8) 3K helmet/MBU-12/P mask/Night Vision Device/Helmet Mounted Display

Each subject was fitted with a skull cap, which was used inside the helmet for a secure fit. Figure A-4 illustrates the HGU-55/P helmet, MBU-12/P mask and the skull cap removed from the helmet. Figure A-5 illustrates the HGU-26/P helmet and MBU-5/P mask. Figure A-6 illustrates the 3G helmet, MBU-12/P mask, night vision device and the skull cap. Figure A-7 illustrates the 3H helmet, MBU-12/P mask, night vision device and the skull cap. Figure A-8 illustrates the 3K helmet, MBU-12/P mask, night vision device and the skull cap.

## 5. INSTRUMENTATION

The electronic data collected during this test program is described in Sections 5.1 and 5.2. Section 5.1 discusses accelerometers while Section 5.2 discusses load transducers. Section 5.3 discusses the calibration procedures that were used. The measurement instrumentation used in this test program is listed in Tables A-1a through A-1d. These figures

designate the manufacturer, type, serial number, sensitivity and other pertinent data on each transducer used. Table A-2 lists the manufacturer's typical transducer specifications.

Accelerometers and load transducers were chosen to provide the optimum resolution over the expected test load range. Full scale data ranges were chosen to provide the expected full scale range plus 50% to assure the capture of peak signals. All transducer bridges were balanced for zero output prior to the start of each test. The accelerometers were adjusted for the effect of gravity using computer processing software. The component of a 1 G vector in line with the force of gravity that lies along the accelerometer axis was added to each accelerometer.

The accelerometer and load transducer coordinate systems are shown in Figure A-9. The seat coordinate system is right-handed with the z axis parallel to the seat back and positive upward. The x axis is perpendicular to the z axis and positive eyes forward from the subject. The y axis is perpendicular to the x and z axes according to the right hand rule. The origin of the seat coordinate system is designated as the seat reference point (SRP). The SRP is at the midpoint of the line segment formed by the intersection of the seat pan and seat back. All vector components (for accelerations, angular accelerations, forces, moments, etc.) were positive when the vector component (x, y and z) was in the direction of the positive axis.

The linear accelerometers were wired to provide a positive output voltage when the acceleration experienced by the accelerometer was applied in the +x, +y and +z directions, as shown in Figure A-9.

The angular Ry accelerometers were wired to provide a positive output voltage when the angular acceleration experienced by the angular accelerometer was applied in the +y direction according to the right hand rule, as shown in Figure A-9.

The load cells and load links were wired to provide a positive output voltage when the force exerted by the load cell on the subject was applied in the +x, +y or +z direction as shown in Figure A-9.

All transducers except the carriage accelerometers and the carriage velocity tachometer were referenced to the seat coordinate system. The carriage tachometer was wired to provide a positive output voltage during freefall. The carriage accelerometers were referenced to the carriage coordinate system, as shown in Figure A-9.

The ADAM manikin internal transducers were referenced to the manikin coordinate system which is shown in Figure A-10.

The manikin head and lumbar load cells were wired to provide a positive output voltage when the force exerted by the load cell, on the head or lumbar, was applied in the +x, +y or +z directions as shown in Figure A-10.

The manikin My torque transducers were wired to provide a positive output voltage when the torque experienced by the transducers was applied in the +y direction according to the right hand rule, as shown in Figure A-10.

Carriage velocity was measured using a Globe Industries tachometer Model 22A672-2. The rotor of the tachometer was attached to an aluminum wheel with a rubber "O" ring around its circumference to assure good rail contact. The wheel contacted the track rail and rotated as the carriage moved, producing an output voltage proportional to the velocity.

## 5.1 Accelerometers

This section describes the accelerometer instrumentation as required in the AL/CFBE test plan.

Human head accelerations were measured using three Endevco Model 2264-200 linear accelerometers and one Endevco Model 7302A angular (Ry) accelerometer. The accelerometers were mounted to the external edge of a plastic dental bite block. Each subject had his own set of custom fitted dental inserts that were used to support the bite block in his mouth. The bite block inserts into the mask. Figures A-11 and A-12 illustrate the human head accelerometer package.

The chest accelerometer package consisted of three Endevco Model 7264-200 linear accelerometers mounted to a 1/2 x 1/2 x 1/2 inch aluminum block. An Endevco Model 7302A angular (Ry) accelerometer was mounted on a bracket adjacent to the triaxial chest block. The accelerometer packages were inserted into a steel protection shield to which a length of Velcro fastener strap was attached. The package was placed over the subject's sternum at the level of the xyphoid and was held there by fastening the Velcro strap around the subject's chest. A chest fiducial target was attached directly on top of the chest accelerometer package. Figure A-13 illustrates the chest accelerometer package.

Carriage accelerations were measured using three Endevco linear accelerometers: one model 2262A-200 for acceleration in the z direction and two models 2264-200 for accelerations in the x and y directions. The

three accelerometers were mounted on a small acrylic block and located behind the seat on the VIP seat structure.

Seat accelerations were measured using three Endevco linear accelerometers: two Models 2264-150 for accelerations in the x and z directions and one model 2264-200 for acceleration in the y direction. The three linear accelerometers were attached to a 1 x 1 x 3/4 inch acrylic block and were mounted near the center of the load cell mounting plate.

Head accelerations for manikin tests were measured using three Endevco Model 2264-200 linear accelerometers and one Endevco Model 7302B angular (Ry) accelerometer. These accelerometers were internally mounted in the head of the manikin.

## 5.2 Load Transducers

This section describes the load transducer instrumentation as required in the AL/CFBE test plan.

The load transducer locations and dimensions are shown in Figures A-14a and A-14b.

Shoulder/anchor forces were measured using one GM/DYN 3D-SW and two AAMRL/DYN 3D-SW triaxial load cells, each capable of measuring forces in the x, y and z directions. The parameters measured are indicated below:

Shoulder x, y and z force
Left lap belt x, y and z force
Right lap belt x, y and z force

The lap/vertical anchor force triaxial load cells were located on separate brackets mounted on the side of the seat frame parallel to the seat pan.

The shoulder strap force triaxial load cell was mounted on the seat frame between the seat back support plate and the headrest.

Left, right and center seat forces were measured using three load cells and three load links. The three load cells included three Strainsert Model FL2.5U-2SPKT load cells. The three load links, as shown in Figure A-15, were fabricated by DynCorp using Micro Measurement Model EA-06-062TJ-350 strain gages. All six measurement devices were located under the seat pan support plate. The load links were used for measuring loads in the x and y directions, two in the x direction and one in the y direction. Each load link housed a swivel ball which acted as a coupler

between the seat pan and load cell mounting plate. The Strainsert load cells were used for measuring loads in the z direction. The seat pan instrumentation and the lap belt anchor load cells can be seen in Figure A-16.

Upper and lower headrest x forces were each measured using two Strainsert Model FL1U-2SG load cells. The load cells were mounted on a rectangular mounting plate which was attached to the upper seat back. The headrest was attached directly to the load cells. The mounting plate/load cells/headrest was adjusted up or down depending on the location of the subjects head. The headrest and shoulder belt anchor load cells can be seen in Figure A-17.

For large ADAM manikin tests, Lumbar x, y and z forces and My torque, and Neck x, y and z forces and My torque were each measured using Denton Model 1914 and 1716 load cells respectively. These load cells were internally mounted in the manikins.

## 5.3 Calibration

Calibrations were performed before and after testing to confirm the accuracy and functional characteristics of the transducers. Pre-program and post-program calibrations are given in Tables A-3a through A-3e.

The calibration of all Strainsert load cells was performed by the Precision Measurement Equipment Laboratories (PMEL) at Wright-Patterson Air Force Base. PMEL calibrated these devices on a periodic basis and provided current sensitivity and linearity data.

The calibration of the accelerometers was performed by DynCorp using the comparison method (Ensor, 1970). A laboratory standard accelerometer, calibrated on a yearly basis by Endevco with standards traceable to the National Bureau of Standards, and a test accelerometer were mounted on a shaker table. The frequency response and phase shift of the test accelerometer were determined by driving the shaker table with a random noise generator and analyzing the outputs of the accelerometers with a Zenith 248/12 computer using Fourier analysis. The natural frequency and the damping factor of the test accelerometer were determined, recorded and compared to previous calibration data for that test accelerometer. Sensitivities were calculated at 40 G and 100 Hertz. The sensitivity of the test accelerometer was determined by comparing its output to the output of the standard accelerometer.

The angular accelerometers were calibrated by DynCorp by comparing their output to the output of a linear standard accelerometer. The angular

accelerometer is mounted parallel to the axis of rotation of a Honeywell low inertia D. C. motor. The standard accelerometer is mounted perpendicular to the axis of rotation at a radius of one inch to measure the tangential acceleration. The D. C. motor motion is driven at a constant sinusoidal angular acceleration of 100 Hertz and the sensitivity is calculated by comparing the rms output voltages of the angular and linear accelerometers.

The shoulder/lap triaxial load cells and load links were calibrated by DynCorp. These transducers were calibrated to a laboratory standard load cell in a special test fixture. The sensitivity and linearity of each test load cell were obtained by comparing the output of the test load cell to the output of the laboratory standard under identical loading conditions. The laboratory standard load cell, in turn, is calibrated by PMEL on a periodic basis.

The velocity wheel is calibrated periodically by DynCorp by rotating the wheel at approximately 2000, 4000 and 6000 revolutions per minute (RPM) and recording both the output voltage and the RPM.

## 6. DATA ACQUISITION

Data acquisition was controlled by a comparator on the Master Instrumentation Control Unit in the Instrumentation Station. The test was initiated when the comparator countdown clock reached zero. The comparator was set to start data collection at a preselected time.

A reference mark pulse was generated to mark the ADACS electronic data at a preselected time after test initiation to place the reference mark close to the impact point. At the same time, the reference mark pulse triggered a strobe light to mark the test photogrammetric data. The reference mark time was used as the start time for data processing of the electronic and photogrammetric data.

Prior to each test and prior to placing the subject in the seat, data were recorded to establish a zero reference for all data transducers. These data were stored separately from the test data and were used in the processing of data.

### 6.1 Automatic Data Acquisition and Control System (ADACS)

Installation of the ADACS instrumentation is shown in Figure A-18. The three major components of the ADACS system are the power conditioner, signal conditioners and the encoder. A block diagram of the ADACS is

shown in Figure A-19. The signal conditioners contain forty-eight amplifiers with programmable gain and filtering.

Bridge excitation for load cells and accelerometers was 10 VDC. Bridge completion and balance resistors were added as required to each module input connector.

The forty-eight module output data signals were digitized and encoded into forty-eight 11-bit digital words. Two additional 11-bit synchronization (sync) words were added to the data frame making a fifty word capability.

Three synchronization pulse trains (bit sync, word sync and frame sync) were added to the data frame and sent to the computer via a junction box data cable.

The PDP 11/34 minicomputer received serial data from the ADACS. The serial data coming from the carriage are converted to parallel data in the data formatter. The data formatter inputs data by direct memory access (DMA) into the computer memory via a buffered data channel where data are temporarily stored on disk. Data are later transferred to the VAX 11/750 and output to magnetic tape for permanent storage. The interrelationships among the data acquisition and storage equipment are shown in Figure A-20.

Test data could be reviewed immediately after each test by using the "quick look" SCAN routine. SCAN was used to produce a plot of the data stored on any channel as a function of time. The routine determined the minimum and maximum values of any data plot. It was also used to calculate the rise time, pulse duration and carriage acceleration and create a disk file containing significant test parameters.

## 6.2 Photogrammetric Data Acquisition

Two onboard high-speed LOCAM cameras, operating at 500 frames per second, were used to produce the photogrammetric data. The side camera was a LOCAM Model 50-0002 (S/N 387) and the oblique camera was a LOCAM Model 50-0002 (S/N 374). The side and oblique cameras each used a 9 mm lens (S/N 69519 and 72019 respectively). The two camera locations are shown in Figure A-21.

Motion of the subjects' helmet, mask, neck, shoulder and chest were quantified by tracking the motion of subject-mounted fiducials. Reference fiducials were placed on the test fixture. The fiducial used was a .75" diameter black circle on a 1.25" diameter white target. The locations of the fiducials generally followed the guidelines provided in

"Film Analysis Guides for Dynamic Studies of Test Subjects, Recommended Practice" (SAE J138, March 1980). Figures A-22 and A-23 identify the fiducial target locations.

All cameras were automatically started at a preset time in the test sequence by a signal from the camera and lighting control station.

The photogrammetric data were time correlated in each test. Immediately prior to impact, a reference mark signal triggered the flash unit to mark the camera film frame. At that time, a 100 PPS signal activated the camera light emitting diode (LED) driver which activated the camera LED, producing a time mark at the film edge. This reference mark was then used to correlate the photogrammetric data with the electronically measured data.

The photogrammetric data will be processed as required on the Automatic Film Reader (AFR) system, shown in the block diagram in Figure A-24. The fiducial tracking routine is initiated via the Data General terminal. The tracking routine is booted from a floppy disk into the Nova 3/12 memory. The system is capable of tracking fiducials manually or automatically. The Nova 3/12 outputs an x-y film coordinate position to magnetic tape for each fiducial being tracked. Data are transferred from magnetic tape to the DEC PDP 11/34 disk file and then transferred to the DEC VAX 11/750 disk file for processing.

A Kodak Ektapro 1000 video system was also used to provide coverage of each test. This video recorder and display unit is capable of recording high-speed motion up to a rate of 1000 frames per second. Immediate replay of the impact is possible in real time or in slow motion.

## 7. PROCESSING PROGRAMS

The executable images for the ADACS processing programs are located in directory PROCESS of the VAX 11/750 and the test data is assumed to be stored in logical directory DATADIR. All plots and the test summary sheet are output to the LNØ3 laser printer. The test base file is output to directory PROCESS.

### 7.1 ADACS Program Operation

The two Fortran programs that process the ADACS test data for the VCSI Study (Vertical Deceleration Tower facility) are named VCSIVDTØA and VCSIVDTØB. The DCL file which controls the execution of these programs is named VCSIVDT. The character string 'VCSI' identifies the study, 'VDT' identifies the facility (Vertical Deceleration Tower), 'Ø' is the

revision number, and the last character determines the program order of execution.

VCSIVDTØA accepts user input and creates a temporary DCL file which controls the sequential batch processing of a specified number of tests. VCSIVDTØA requests the user to enter the total number of tests to be processed and the test number of each test. Logical directory DATADIR is assumed to contain a zero reference file named '<test no>Z.VDT', a test data file named '<test no>D.VDT' and a sensitivity file named '<test no>S.VDT'.

The default test parameters are retrieved from the header block of the test data file and displayed as a menu on the screen. The user may specify new values for any of the displayed test parameters. The test parameters include the subject ID, weight, age, height and sitting height. Additional parameters include the cell type, nominal G level, subject type (manikin or human) and belt preload status (computed or not computed). If the belt preloads were computed, then the shoulder and lap preloads are also displayed.

VCSIVDTØB generates time histories for the carriage and seat x, y, and z axis linear accelerations and the carriage velocity. Time histories for the head and chest linear and angular accelerations and the resultant linear accelerations are computed. Other quantities include the shoulder, left and right lap x, y and z axis forces, headrest forces, and x, y and z axis seat forces. Resultants are computed for the shoulder, left lap, right lap and seat. The seat z force is corrected to subtract out the force due to the mass of the seat pan. The dynamic response of the DRI model is computed for the seat z axis acceleration.

The impact rise time, duration and velocity change are computed and stored in the test base file. Values for the preimpact level and the extrema for each time history are stored in the test base file and printed out as a summary sheet for each test. The time histories are also plotted.

### 7.2 ADACS Program Flowcharts

Flowcharts of the two programs are shown in Figures A-25 and A-26. Each flowchart identifies the files used and the subroutines called by the program. Some of the subroutines which are not flowcharted are located in user libraries. Others have such a simple structure that they do not require flowcharting.

# DIGITAL INSTRUMENTATION REQUIREMENTS

**DYNCORP**

PROGRAM VISUALLY COUPLED SYSTEMS IMPACT (VCSI) +Gz DATE 24 JUL 90 THRU 08 APR 91

FACILITY VERTICAL DECELERATION TOWER RUN 1811 THRU 2177

| DATA CHANNEL | DATA POINT | XDUCER MFG & TYPE | SERIAL NUMBER | XDUCER SENS | EXCITE V | CHAN | FILTER SERIES | FILTER S/N | AMP GAIN | AMP S/N | SAMPLE RATE | SAMPLE FORMAT | FULL SCALE SENS. | FILTER HZ | XDUCER ZERO | RANGE | BRIDGE BALANCE RESISTORS | BRIDGE COMP RESISTORS | SPECIAL NOTATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CARRIAGE z ACCEL. | ENDEVCO 2262 A-200 | FR31 | 5.037 mv/G | 10.00 | 1 | 60 | 1 | 10 | 1 | 1K | 1 | 46.6G | 120 | 2.5 | +5.0 0.0 | 108K +IN GND. | - | |
| 2 | CARRIAGE x ACCEL. | ENDEVCO 2264-200 | BQ47 | 3.167 mv/G | 10.00 | 2 | 60 | 2 | 50 | 25 | 1K | 1 | 15.8G | 120 | 2.5 | +5.0 0.0 | - | 1.5K | |
| 3 | CARRIAGE y ACCEL. | ENDEVCO 2264-200 | BN61 | 2.907 mv/G | 10.00 | 3 | 60 | 3 | 50 | 8 | 1K | 1 | 17.2G | 120 | 2.5 | +5.0 0.0 | 172K +IN GND. | 1.5K | |
| 4 | DUMMY HEAD z ACCEL. | ENDEVCO 2264-200 | CN74 | 2.946 mv/G | 10.00 | 4 | 60 | 4 | 25 | 36 | 1K | 1 | 33.9G | 120 | 2.5 | +5.0 0.0 | 200K +IN GND. | 1.5K | |
| 5 | DUMMY HEAD y ACCEL. | ENDEVCO 2264-200 | BQ42 | 2.711 mv/G | 10.00 | 5 | 60 | 5 | 25 | 24 | 1K | 1 | 36.9G | 120 | 2.5 | +5.0 0.0 | 164K +IN GND. | 1.5K | |
| 6 | DUMMY HEAD z ACCEL. | ENDEVCO 2264-200 | CN73 | 2.741 mv/G | 10.00 | 6 | 60 | 6 | 10 | 5 | 1K | 1 | 91.2G | 120 | 2.5 | +5.0 0.0 | - | 1.5K | |
| 7 | DUM. HEAD Ry ANG. ACCEL. | ENDEVCO 7302B | TJ75 | 3.793 uv/RAD/SEC2 | 10.00 | 7 | 60 | 7 | 100 | 14 | 1K | 1 | 6591 RAD/SEC2 | 120 | 2.5 | +5.0 0.0 | 500K +IN GND. | - | |
| 8 | CHEST x ACCEL. | ENDEVCO 7264-200 | BH76H | 3.194 mv/G | 10.00 | 8 | 60 | 8 | 25 | 1 | 1K | 1 | 31.3G | 120 | 2.5 | +5.0 0.0 | 76K +IN GND. | 1.5K | |
| 9 | CHEST y ACCEL. | ENDEVCO 7264-200 | BH81H | 3.261 mv/G | 10.00 | 9 | 60 | 9 | 50 | 5 | 1K | 1 | 15.3G | 120 | 2.5 | +5.0 0.0 | - | 1.5K | |
| 10 | CHEST z ACCEL. | ENDEVCO 7264-200 | BH87H | 2.996 mv/G | 10.00 | 10 | 60 | 10 | 10 | 24 | 1K | 1 | 83.4G | 120 | 2.5 | +5.0 0.0 | 100K +IN GND. | 1.5K | |
| 11 | CHEST Ry ANG. ACCEL. | ENDEVCO 7302A | AB15 | 6.68 uv/RAD/SEC2 | 10.00 | 11 | 60 | 11 | 100 | 27 | 1K | 1 | 3743 RAD/SEC2 | 120 | 2.5 | +5.0 0.0 | - | - | |
| 12 | LEFT SEAT z FORCE | STRAINSERT FL2.5U-2 SPKT | 7135-4 | 7.96 uv/LB | 10.00 | 12 | 60 | 12 | 100 | 6 | 1K | 1 | 3141LB | 120 | 2.5 | +5.0 0.0 | - | - | TESTS 1811-2167, S/N 7135-2, SENS. @ 7.93 uv/LB, F.S. 3153 LB. |
| 13 | RIGHT SEAT z FORCE | STRAINSERT FL2.5U-2 SPKT | 7135-3 | 7.88 uv/LB | 10.00 | 13 | 60 | 13 | 100 | 22 | 1K | 1 | 3173LB | 120 | 2.5 | +5.0 0.0 | - | - | TESTS 1811-2090, S/N 7135-4, SENS. 7.92 uv/LB, F.S. 3157 LB. |
| 14 | CENTER SEAT z FORCE | STRAINSERT FL2.5U-2 SPKT | 3294-3 | 8.05 uv/LB | 10.00 | 14 | 60 | 14 | 50 | 10 | 1K | 1 | 6211LB | 120 | 2.5 | +5.0 0.0 | - | - | TESTS 1811-2090, S/N 3294-5, SENS. 8.03 uv/LB, F.S. 6227 LB. |

COMPARATORS -
COMPUTER START: -6
COMPUTER STOP: +3

MAG TAPE (ANALOG TESTS ONLY)

NOTE: TESTS 1961 THROUGH 2177

HUMAN TESTS WILL USE IDENTICAL CHANNELS AND GAINS FOR HEAD.

CHANNELS 31, 34-36, 39-42 NOT USED FOR HUMAN TESTS.

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TABLE A-1a: INSTRUMENTATION REQUIREMENTS

| DIGITAL INSTRUMENTATION REQUIREMENTS | DYNCORP |
|---|---|
| PROGRAM VISUALLY COUPLED SYSTEMS IMPACT (VCSI) +Gz DATE 24 JUL 90 THRU 08 APR 91 | |
| FACILITY VERTICAL DECELERATION TOWER RUN 1811 THRU 2177 | |

| DATA CHANNEL | DATA POINT | XDUCER MFG & TYPE | SERIAL NUMBER | XDUCER SENS | EXCITE V | EXCITE CHAN | FILTER SERIES | FILTER S/H | AMP GAIN | AMP S/H | SAMPLE RATE | SAMPLE FORMAT | FULL SCALE SENS. | FILTER HZ | XDUCER ZERO | XDUCER RANGE | BRIDGE BALANCE RESISTORS | BRIDGE COMP RESISTORS | SPECIAL NOTATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | LEFT SEAT x FORCE | MM/DYN EA-06-06 2TJ-350 | 003 | 11.18 uv/LB | 10.00 | 15 | 60 | 15 | 201 | 13 | 1K | 1 | 1113 LB | 120 | 2.5 | +5.0 0.0 | - | - | |
| 16 | RIGHT SEAT x FORCE | MM/DYN EA-06-06 2TJ-350 | 3 | *10.88 uv/LB | 10.00 | 16 | 60 | 16 | 201 | 5 | 1K | 1 | 1143 LB | 120 | 2.5 | +5.0 0.0 | - | - | * TESTS 1811-1836, S/N 4, 1234 LB F.S., SENS. 10.08 uv/LB |
| 17 | CENTER SEAT y FORCE | MM/DYN EA-06-06 2TJ-350 | 1 | 10.64 uv/LB | 10.00 | 17 | 60 | 17 | 201 | 17 | 1K | 1 | 1169 LB | 120 | 2.5 | +5.0 0.0 | - | - | |
| 18 | LEFT LAP x LOAD | AAMRL/DYN 3D-SW | 24X | 7.45 uv/LB | 10.00 | 18 | 60 | 18 | 201 | 16 | 1K | 1 | 1670 LB | 120 | 2.5 | +5.0 0.0 | - | - | |
| 19 | LEFT LAP y LOAD | AAMRL/DYN 3D-SW | 24Y | 7.09 uv/LB | 10.00 | 19 | 60 | 19 | 402 | 12 | 1K | 1 | 877 LB | 120 | 2.5 | +5.0 0.0 | - | - | |
| 20 | LEFT LAP z LOAD | AAMRL/DYN 3D-SW | 24Z | 7.90 uv/LB | 10.00 | 20 | 60 | 20 | 201 | 15 | 1K | 1 | 1574 LB | 120 | 2.5 | +5.0 0.0 | - | - | |
| 21 | RIGHT LAP x LOAD | AAMRL/DYN 3D-SW | 25X | 6.98 uv/LB | 10.00 | 21 | 60 | 21 | 201 | 8 | 1K | 1 | 1782 LB | 120 | 2.5 | +5.0 0.0 | - | - | |
| 22 | RIGHT LAP y LOAD | AAMRL/DYN 3D-SW | 25Y | 7.26 uv/LB | 10.00 | 22 | 50 | 22 | 402 | 18 | 1K | 1 | 857 LB | 120 | 2.5 | +5.0 0.0 | 22K +IN GND. | - | |
| 23 | RIGHT LAP z LOAD | AAMRL/DYN 3D-SW | 25Z | 7.83 uv/LB | 10.00 | 23 | 50 | 24 | 201 | 3 | 1K | 1 | 1589 LB | 120 | 2.5 | +5.0 0.0 | 31K +IN GND. | | |
| 24 | VELOCITY | GLOBE 22A672-2 | 4 | .0612 V/F/S | - | 24 | 30 | 1 | -1 | - | 1K | 1 | 81.7 F/S | 60 | -0- | +5.0 0.0 | - | - | SIGNAL ATTENUATED BY 7.65 SENS. = .468÷7.65=.0612 V/F/S NEG OUTPUT WHEN FALLING |
| 25 | SHOULDER x LOAD | GM/DYN 3D-SW | 20Z | 6.31 uv/LB | 10.00 | 25 | 60 | 25 | 402 | 6 | 1K | 1 | 986 LB | 120 | 2.5 | +5.0 0.0 | 33K +IN GND | - | |
| 26 | SHOULDER y LOAD | GM/DYN 3D-SW | 20Y | 5.38 uv/LB | 10.00 | 26 | 60 | 26 | 800 | 5 | 1K | 1 | 581 LB | 120 | 2.5 | +5.0 0.0 | 76K -IN GND | - | |
| 27 | SHOULDER z LOAD | GM/DYN 3D-SW | 20X | 4.95 uv/LB | 10.00 | 27 | 60 | 27 | 402 | 9 | 1K | 1 | 1256 LB | 120 | 2.5 | +5.0 0.0 | 43K +IN GND | - | |
| 28 | SEAT x ACCEL. | ENDEVCO 2264-150 | BN39 | 3.137 mv/G | 10.00 | 28 | 60 | 28 | 50 | 2 | 1K | 1 | 15.9G | 120 | 2.5 | +5.0 0.0 | - | - | |

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TABLE A-1b: INSTRUMENTATION REQUIREMENTS

## DIGITAL INSTRUMENTATION REQUIREMENTS

# DYNCORP

PROGRAM VISUALLY COUPLED SYSTEMS IMPACT (VCSI) +Gz DATE 24 JUL 90 THRU 08 APR 91

FACILITY VERTICAL DECELERATION TOWER RUN 1811 THRU 2177

| DATA CHANNEL | DATA POINT | XDUCER MFG & TYPE | SERIAL NUMBER | XDUCER SENS | EXCITE V | EXCITE CHAN | FILTER SERIES | FILTER S/N | AMP GAIN | AMP S/N | SAMPLE RATE | SAMPLE FORMAT | FULL SCALE SENS. | FILTER HZ | XDUCER ZERO | XDUCER RANGE | BRIDGE BALANCE RESISTORS | BRIDGE COMP RESISTORS | SPECIAL NOTATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | SEAT y ACCEL. | ENDEVCO 2264-200 | BX17 | 2.735 mv/G | 10.00 | 29 | 60 | 29 | 50 | 22 | 1K | 1 | 18.3G | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 30 | SEAT z ACCEL | ENDEVCO 2264-150 | BB32 | 2.648 mv/G | 10.00 | 30 | 60 | 30 | 25 | 20 | 1K | 1 | 37.8G | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 31 | LEFT ADAM NECK My | DENTON 1716 | LC127-1 | 6.52 uv/LB-IN | 10.00 | 31 | 60 | 38 | 50 | 35 | 1K | 1 | 7669 LB-IN | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 32 | UPPER HEADREST x FORCE | STRAINSERT FL1U-2SG | 0207 | 20.29 uv/LB | 10.00 | 32 | 60 | 32 | 201 | 1 | 1K | 1 | 613 LB | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 33 | LOWER HEADREST x FORCE | STRAINSERT FL1U-2SG | 0218 | 20.00 uv/LB | 10.00 | 33 | 60 | 33 | 201 | 12 | 1K | 1 | 622 LB | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 34 | L. ADAM NECK x FORCE | DENTON 1716 | LC127-1 | 7.98 uv/LB | 10.00 | 34 | 60 | 34 | 100 | 34 | 1K | 1 | 3133 LB | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 35 | L. ADAM NECK y FORCE | DENTON 1716 | LC127-1 | 7.95 uv/LB | 10.00 | 35 | 60 | 35 | 201 | 6 | 1K | 1 | 1565 LB | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 36 | L. ADAM NECK z FORCE | DENTON 1716 | LC127-1 | 4.45 uv/LB | 10.00 | 36 | 60 | 36 | 201 | 9 | 1K | 1 | 2795 LB | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 39 | L. ADAM LUMBAR x FORCE | DENTON 1914 | 041 | 6.29 uv/LB | 10.00 | 39 | 60 | 39 | 50 | 32 | 1K | 1 | 7949 LB | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 40 | L. ADAM LUMBAR y FORCE | DENTON 1914 | 041 | 6.31 uv/LB | 10.00 | 40 | 60 | 40 | 100 | 17 | 1K | 1 | 3962 LB | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 41 | L. ADAM LUMBAR z FORCE | DENTON 1914 | 041 | 2.68 uv/LB | 10.00 | 41 | 60 | 41 | 100 | 33 | 1K | 1 | 9328 LB | 120 | 2.5 | ±5.0 0.0 | - | - | |
| 42 | L. ADAM LUMBAR My | DENTON 1914 | 041 | 5.05 uv/LB-IN | 10.00 | 42 | 60 | 42 | 25 | 10 | 1K | 1 | 19800 LB-IN | 120 | 2.5 | ±5.0 0.0 | - | - | |
| *45 | EVENT REFERENCE | - | - | 1.0 VOLT | - | 45 | 1000 | 3 | 2.5 | 19 | 1K | 1 | 2.5 VOLT | 2000 | 5.0 | ±5.0 0.0 | - | - | * TESTS 1811-1884, CHANNEL 37 |
| *46 | TO PULSE | - | - | 1.0 VOLT | - | 46 | 1000 | 12 | 1 | - | 1K | 1 | 5.0 VOLT | 2000 | 5.0 | ±5.0 0.0 | - | - | * TESTS 1811-1846, CHANNEL 38 |

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TABLE A-1c: INSTRUMENTATION REQUIREMENTS

**DIGITAL INSTRUMENTATION REQUIREMENTS**

**DYNCORP**

PROGRAM VISUALLY COUPLED SYSTEMS IMPACT (VCSI) +Gz DATE 24 JUL 90 THRU 08 APR 91

FACILITY VERTICAL DECELERATION TOWER RUN 1811 THRU 2177

| DATA CHANNEL | DATA POINT | XDUCER MFG & TYPE | SERIAL NUMBER | XDUCER SENS | EXCITE V | CHAN | FILTER SERIES | S/N | AMP GAIN | S/N | SAMPLE RATE | FORMAT | FULL SCALE SENS. | FILTER HZ | XDUCER ZERO | RANGE | BRIDGE BALANCE RESISTORS | BRIDGE COMP RESISTORS | SPECIAL NOTATIONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47 | BIAS VOLTAGE | - | - | 1.0 VOLT | - | 47 | 180 | 3 | 1 | - | 1K | 1 | 2.5 VOLT | 360 | 0.0 | +5.0 0.0 | - | - | |
| 48 | 10 VOLT EXCITATION | - | - | 1.0 VOLT | 10.00 | 48 | 180 | 8 | 1 | - | 1K | 1 | 2.5 VOLT | 360 | 0.0 | +5.0 0.0 | - | - | |
| | | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | | |
| SUPPLEMENT FOR TESTS 1961 - 2177 DATED 04 OCT 90 - 08 APR 91 | | | | | | | | | | | | | | | | | | | |
| 4 | HUMAN HEAD x ACCEL. | ENDEVCO 2264-200 | CB09 | 2.920 mv/G | 10.00 | 4 | 60 | 4 | 25 | 36 | 1K | 1 | 34.2G | 120 | 2.5 | +5.0 0.0 | | 1.6K | |
| 5 | HUMAN HEAD y ACCEL. | ENDEVCO 2264-200 | BV95 | 2.966 mv/G | 10.00 | 5 | 60 | 5 | 25 | 24 | 1K | 1 | 33.7G | 120 | 2.5 | +5.0 0.0 | | 1.6K | TEST 1970 MOUTH PACK PLACED 180° OFF AXIS. |
| 6 | HUMAN HEAD z ACCEL. | ENDEVCO 2264-200 | BW36 | 3.195 mv/G | 10.00 | 6 | 60 | 6 | 10 | 5 | 1K | 1 | 78.2G | 120 | 2.5 | +5.0 0.0 | | 1.5K | TEST 1970 MOUTH PACK PLACED 180° OFF AXIS. |
| 7 | HUMAN HEAD Ry ANG. ACCEL. | ENDEVCO 7302A | AB12 | 4.20 uv/RAD/SEC2 | 10.00 | 7 | 60 | 7 | 100 | 14 | 1K | 1 | 5952 RAD/SEC2 | 120 | 2.5 | +5.0 0.0 | | - | |
| | | | | | | | | | | | | | | | | | | | |
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TABLE A-1d: INSTRUMENTATION REQUIREMENTS

| MANUFACTURER | MODEL | RANGE | SENSITIVITY (mv) | RESONANCE FREQ (Hz) | FREQUENCY RESPONSE (Hz.) | EXCITATION (Volt) | 2 ARM or 4 ARM | ADDITIONAL NOTES |
|---|---|---|---|---|---|---|---|---|
| Endevco | 2264-150 | ± 150 G | 2.5/G | 3400 | 0-800 | 10 | 2 arm | Linear accelerometer |
| Endevco | 2264-200 | ± 200 G | 2.5/G | 4700 | 0-1200 | 10 | 2 arm | Linear accelerometer |
| Endevco | 7264-200 | ± 200 G | 2.5/G | 6000 | 0-1200 | 10 | 2 arm | Linear accelerometer, |
| Endevco | 2262A-200 | ± 200 G | 2.5/G | 7000 | 0-2000 | 10 | 4 arm | Linear accelerometer, |
| Endevco | 7302A | ± 50,000 Rad/Sec$^2$ | .0055 /Rad/Sec$^2$ | 2500 | 1-600 | 10 | 4 arm | Angular accelerometer, X10 overrange |
| Endevco | 7302B | ± 50,000 Rad/Sec$^2$ | .004 /Rad/Sec$^2$ | 3000 | 1-600 | 10 | 4 arm | Angular accelerometer, X10 overrange |
| Strainsert | FL2.5U-2SPKT | ± 2500 LB | .008/LB | 3600 | 0-2000 | 10 | 4 arm | Load cell; 15 V max exc.; 5 K LB max. overrange |
| Strainsert | FL1U-2SG | ± 1000 LB | .020/LB | 3600 | 0-2000 | 10 | 4 arm | Load cell; 15 V max exc.; 2 K LB max. overrange |
| Denton | 1914 | ± 5000 LB | - | N/A | N/A | 10 | 4 arm | 6 axis load cell; 15 V max. exc. |
| Denton | 1716 | ± 3000 LB | - | N/A | N/A | 10 | 4 arm | 6 axis load cell; |

TABLE A-2: TYPICAL TRANSDUCER SPECIFICATIONS

# DYNCORP PROGRAM CALIBRATION LOG

**PROGRAM** VISUALLY COUPLED SYSTEMS $^{+Gz}$IMPACT (VCSI) **DATES:** 24 JUL 90 - 08 APR 91

**FACILITY** VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1811 - 2177

| DATA POINT | TRANSDUCER MFG.& MODEL | SERIAL NUMBER | PRE-CAL | | POST-CAL | | %CHANGE | NOTES |
|---|---|---|---|---|---|---|---|---|
| | | | DATE | SENS | DATE | SENS | | |
| CARRIAGE z ACCEL. | ENDEVCO 2262A-200 | FR31 | 28JUN90 | 5.037 mv/G | 11APR91 | 5.0604 mv/G | -.7 | |
| CARRIAGE x ACCEL. | ENDEVCO 2264-200 | BQ47 | 18JAN90 | 3.167 mv/G | 11APR91 | 3.1674 mv/G | -0.3 | |
| CARRIAGE y ACCEL. | ENDEVCO 2264-200 | BN61 | 21NOV89 | 2.907 mv/G | 11APR91 | 2.8846 mv/G | -0.5 | |
| DUMMY HEAD x ACCEL. | ENDEVCO 2264-200 | CH74 | 02MAY90 | 2.946 mv/G | 11APR91 | 2.9429 mv/G | -0.6 | |
| DUMMY HEAD y ACCEL. | ENDEVCO 2264-200 | BQ42 | 02MAY90 | 2.711 mv/G | 11APR91 | 2.7060 mv/G | -0.7 | |
| DUMMY HEAD z ACCEL. | ENDEVCO 2264-200 | CH73 | 11APR90 | 2.741 mv/G | 11APR91 | 2.7449 mv/G | -0.3 | |
| DUMMY HEAD ANG Ry ACCEL. | ENDEVCO 7302B | TJ75 | 04MAY90 | 3.793 uv/RAD/ SEC2 | 15APR91 | 3.892 uv/RAD/ SEC2 | 2.61 | |
| CHEST x ACCEL. | ENDEVCO 7264-200 | BH76H | 03MAY90 | 3.194 mv/G | 11APR91 | 3.1903 mv/G | -0.3 | |
| CHEST y ACCEL. | ENDEVCO 7264-200 | BH81H | 03MAY90 | 3.261 mv/G | 11APR91 | 3.2628 mv/G | -0.2 | |
| CHEST z ACCEL. | ENDEVCO 7264-200 | BH87H | 03MAY90 | 2.996 mv/G | 11APR91 | 2.9853 mv/G | -0.4 | |

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TABLE A-3a: TRANSDUCER PRE- AND POST-CALIBRATION

# DYNCORP PROGRAM CALIBRATION LOG

**PROGRAM** VISUALLY COUPLED SYSTEMS IMPACT (VCSI) +Gz **DATES:** 24 JUL 90 - 08 APR 91

**FACILITY** VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1811 - 2177

| DATA POINT | TRANSDUCER MFG. & MODEL | SERIAL NUMBER | PRE-CAL | | POST-CAL | | %CHANGE | NOTES |
|---|---|---|---|---|---|---|---|---|
| | | | DATE | SENS | DATE | SENS | | |
| CHEST Ry ANG. ACCEL. | ENDEVCO 7302A | AB15 | 04MAY90 | 6.68 uv/RAD/SEC2 | 15APR91 | 6.763 uv/RAD/SEC2 | +1.24 | |
| LEFT SEAT z FORCE | STRAINSERT FL2.5U-2SPKT | 7135-2 | 20MAR90 | 7.93 uv/LB | - | - | - | TESTS 1811-2167 CALIBRATED PERIODICALLY BY PMEL. |
| RIGHT SEAT z FORCE | STRAINSERT FL2.5U-2SPKT | 7135-4 | 30NOV89 | 7.92 uv/LB | - | - | - | CALIBRATED PERIODICALLY BY PMEL: TESTS 2168-2177. |
| CENTER SEAT z FORCE | STRAINSERT FL2.5U-2SPKT | 3294-5 | 30NOV89 | 8.03 uv/LB | - | - | - | TESTS 1811-2090 CALIBRATED PERIODICALLY BY PMEL. |
| LEFT SEAT x FORCE | MM/DYN EA-06-062TJ-350 | 003 | 20JUN89 | 11.18 uv/LB | 17APR91 | 11.06 uv/LB | -1.2 | |
| RIGHT SEAT x FORCE | MM/DYN EA-06-062TJ-350 | 4 | 20JUN89 | 10.08 uv/LB | - | - | - | TEST 1811-1836 ONLY. NEEDS REPAIRED. |
| CENTER SEAT y FORCE | MM/DYN EA-06-062TJ-350 | 1 | 20JUN89 | 10.64 uv/LB | 17APR91 | 10.60 uv/LB | -.38 | |
| LEFT LAP x FORCE | AAMRL/DYN 3D-SW | 24X | 20JUN89 | 7.45 uv/LB | 15APR91 | 7.2951 uv/LB | -2.0 | |
| LEFT LAP y FORCE | AAMRL/DYN 3D-SW | 24Y | 20JUN89 | 7.09 uv/LB | 15APR91 | 6.8837 uv/LB | -2.9 | |
| LEFT LAP z FORCE | AAMRL/DYN 3D-SW | 24Z | 20JUN89 | 7.90 uv/LB | 15APR91 | 7.8481 uv/LB | -.66 | |

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TABLE A-3b: TRANSDUCER PRE- AND POST-CALIBRATION

# DYNCORP PROGRAM CALIBRATION LOG

**PROGRAM** VISUALLY COUPLED SYSTEMS +Gz IMPACT (VCSI) **DATES:** 24 JUL 90 - 08 APR 91

**FACILITY** VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1811 - 2177

| DATA POINT | TRANSDUCER MFG.& MODEL | SERIAL NUMBER | PRE-CAL | | POST-CAL | | %CHANGE | NOTES |
|---|---|---|---|---|---|---|---|---|
| | | | DATE | SENS | DATE | SENS | | |
| RIGHT LAP x FORCE | AAMRL/DYN 3D-SW | 25X | 20JUN89 | 6.98 uv/LB | 15APR91 | 6.7912 uv/LB | -2.7 | |
| RIGHT LAP y FORCE | AAMRL/DYN 3D-SW | 25Y | 20JUN89 | 7.26 uv/LB | 15APR91 | 7.2101 uv/LB | -0.7 | |
| RIGHT LAP z FORCE | AAMRL/DYN 3D-SW | 25Z | 20JUN89 | 7.83 uv/LB | 15APR91 | 7.6686 uv/LB | -2.0 | |
| VELOCITY | GLOBE 22A672-2 | 4 | 27JUL89 | .0612 V/F/S | - | - | - | CALIBRATED PERIODIC-ALLY BY PMEL. |
| SHOULDER x FORCE | GM/DYN 3D-SW | 20Z | 30MAR90 | 6.31 uv/LB | 15APR91 | 6.3058 uv/LB | -0- | |
| SHOULDER y FORCE | GM/DYN 3D-SW | 20Y | 30MAR90 | 5.38 uv/LB | 15APR91 | 5.2857 uv/LB | -1.67 | |
| SHOULDER z FORCE | GM/DYN 3D-SW | 20X | 30MAR90 | 4.95 uv/LB | 15APR91 | 4.8446 uv/LB | -2.2 | |
| SEAT x ACCEL. | ENDEVCO 2264-150 | BN39 | 09JUL90 | 3.137 mv/G | 11APR91 | 3.1327 mv/G | -0.1 | |
| SEAT y ACCEL. | ENDEVCO 2264-200 | BX17 | 28MAR90 | 2.735 mv/G | 11APR91 | 2.7665 mv/G | +1.2 | |
| SEAT z ACCEL. | ENDEVCO 2264-150 | BB32 | 11APR90 | 2.648 mv/G | 11APR91 | 2.6283 mv/G | -0.7 | |

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TABLE A-3c: TRANSDUCER PRE- AND POST-CALIBRATION

# DYNCORP PROGRAM CALIBRATION LOG

**PROGRAM** VISUALLY COUPLED SYSTEMS $+G_z$ IMPACT (VCSI) **DATES:** 24JUL 90 - 08 APR 91

**FACILITY** VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1811 - 2177

| DATA POINT | TRANSDUCER MFG.& MODEL | SERIAL NUMBER | PRE-CAL | | POST-CAL | | %CHANGE | NOTES |
|---|---|---|---|---|---|---|---|---|
| | | | DATE | SENS | DATE | SENS | | |
| UPPER HEADREST x FORCE | STRAINSERT FL1U-2SG | 0207 | 05JAN89 | 20.29 uv/LB | - | - | - | CALIBRATED PERIODIC-ALLY BY PMEL. |
| LOWER HEADREST x FORCE | STRAINSERT FL1U-2SG | 0218 | 09NOV88 | 20.00 uv/LB | - | - | - | CALIBRATED PERIODIC-ALLY BY PMEL. |
| RIGHT SEAT z FORCE | STRAINSERT FL2.5U-2SKPT | 7135-3 | 16NOV90 | 7.88 uv/LB | - | - | - | CALIBRATED PERIODIC-ALLY BY PMEL. |
| CENTER SEAT z FORCE | STRAINSERT FL2.5U-2SKPT | 3294-3 | 30NOV89 | 8.05 uv/LB | - | - | - | CALIBRATED PERIODIC-ALLY BY PMEL. |
| RIGHT SEAT x FORCE | MM/DYN EA-06-062TJ-350 | 3 | 29MAR90 | 10.88 uv/LB | 17APR91 | 10.80 uv/LB | -0.7 | TESTS 1837-2177. |
| | | | | | | | | |
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TABLE A-3d: TRANSDUCER PRE- AND POST-CALIBRATION

# DYNCORP PROGRAM CALIBRATION LOG

**PROGRAM** VISUALLY COUPLED SYSTEMS +Gz IMPACT (VCSI) **DATES:** 24 JUL 90 - 08 APR 91

**FACILITY** VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1811 - 2177

| DATA POINT | TRANSDUCER MFG.& MODEL | SERIAL NUMBER | PRE-CAL | | POST-CAL | | %CHANGE | NOTES |
|---|---|---|---|---|---|---|---|---|
| | | | DATE | SENS | DATE | SENS | | |
| L. ADAM NECK My | DENTON 1716 | LC127-1 My | 20JUL90 | 6.52 uv/IN-LB | | | | ALL LARGE ADAM TRANSDUCERS ON THIS PAGE ARE SRL's RE-SPONSIBILITY. NO POST-CALS WERE SUBMITTED. |
| L. ADAM NECK x FORCE | DENTON 1716 | LC127-1 Fx | 20JUL90 | 7.98 uv/LB | | | | |
| L. ADAM NECK y FORCE | DENTON 1716 | LC127-1 Fy | 20JUL90 | 7.95 uv/LB | | | | |
| L. ADAM NECK z FORCE | DENTON 1716 | LC127-1 Fz | 20JUL90 | 4.45 uv/LB | | | | |
| L. ADAM LUMBAR x FORCE | DENTON 1914 | 041 | 25MAY90 | 6.29 uv/LB | | | | |
| L. ADAM LUMBAR y FORCE | DENTON 1914 | 041 | 25MAY90 | 6.31 uv/LB | | | | |
| L. ADAM LUMBAR z FORCE | DENTON 1914 | 041 | 25MAY90 | 2.68 uv/LB | | | | |
| L. ADAM LUMBAR My | DENTON 1914 | 041 | 25MAY90 | 5.05 uv/LB-IN | | | | |
| | | | | | | | | |
| | | | | | | | | |

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TABLE A-3e: TRANSDUCER PRE- AND POST-CALIBRATION

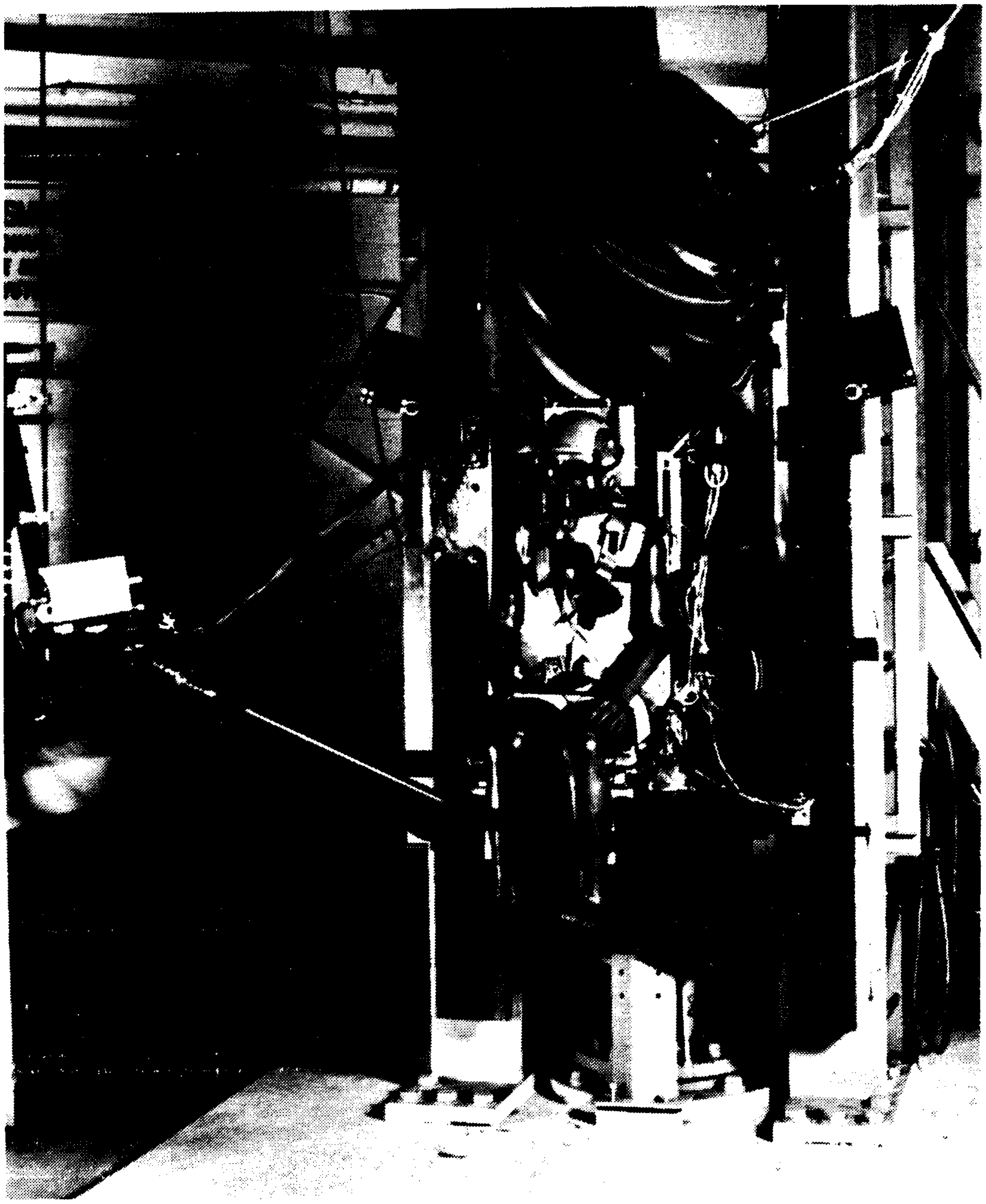


FIGURE A-1: AL/CFBE VERTICAL DECELERATION TOWER

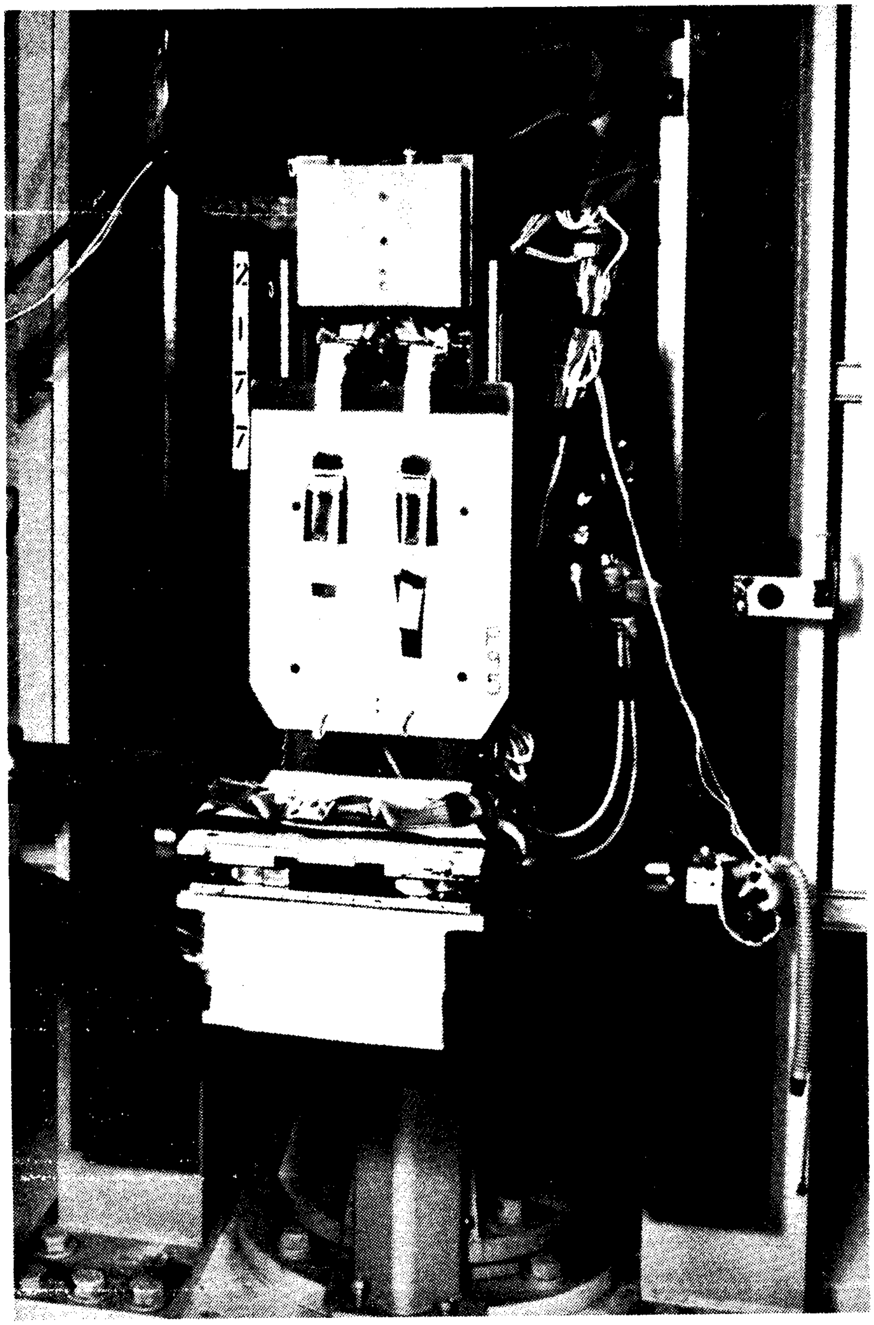


FIGURE A-2: VIP SEAT FIXTURE

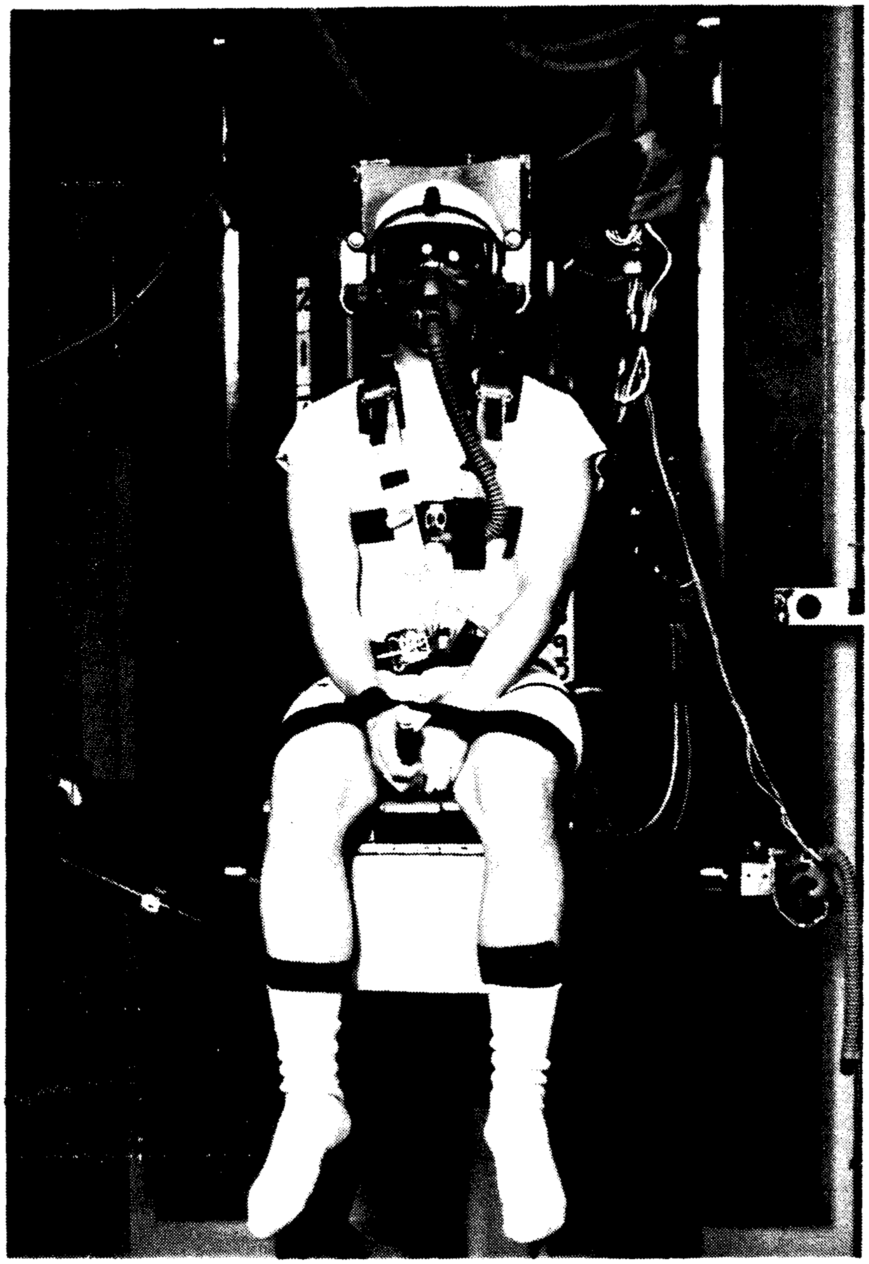


FIGURE A-3: SUBJECT LEG AND THIGH RESTRAINTS


FIGURE A-4: HGU-55/P HELMET/MBU-12/P MASK COMBINATION

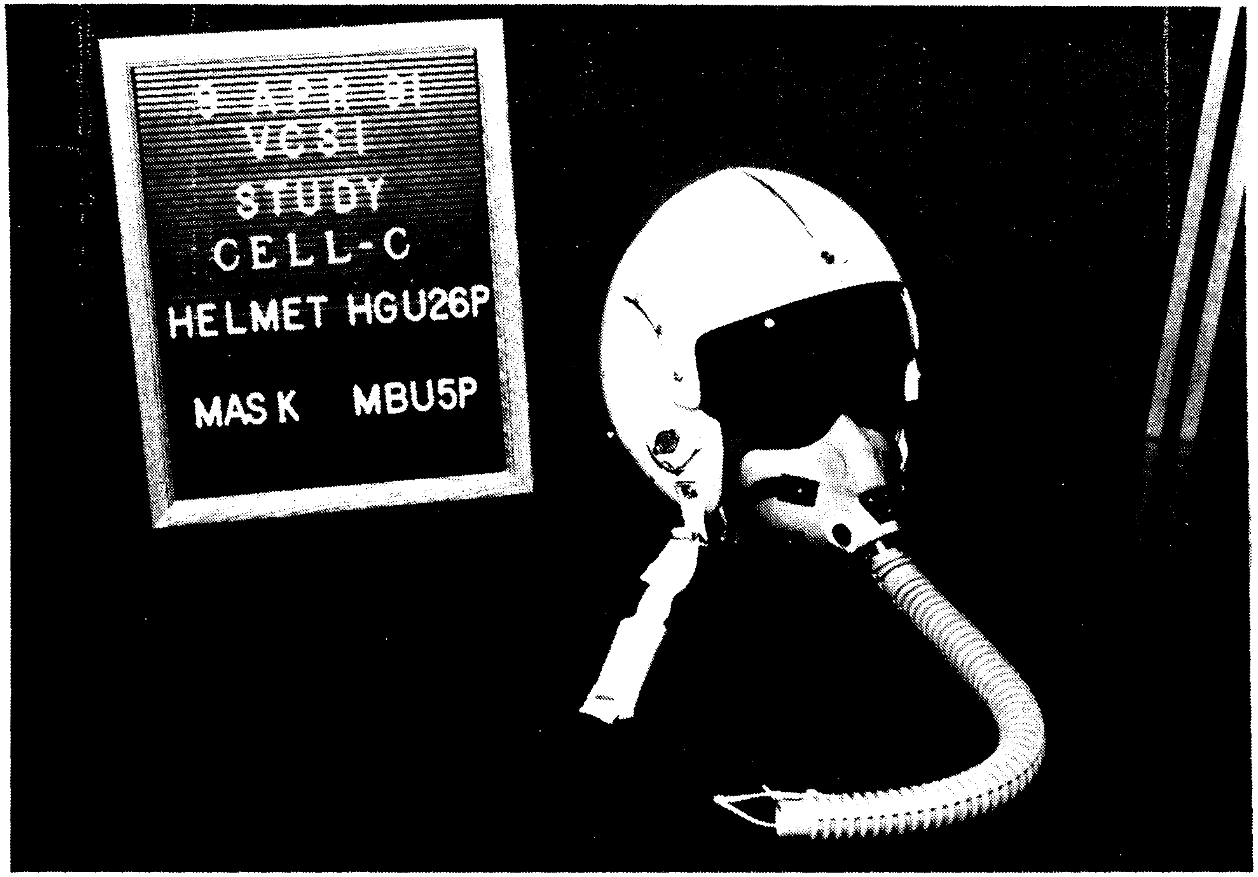



FIGURE A-5: HGU-26/P HELMET/MBU-5/P MASK COMBINATION

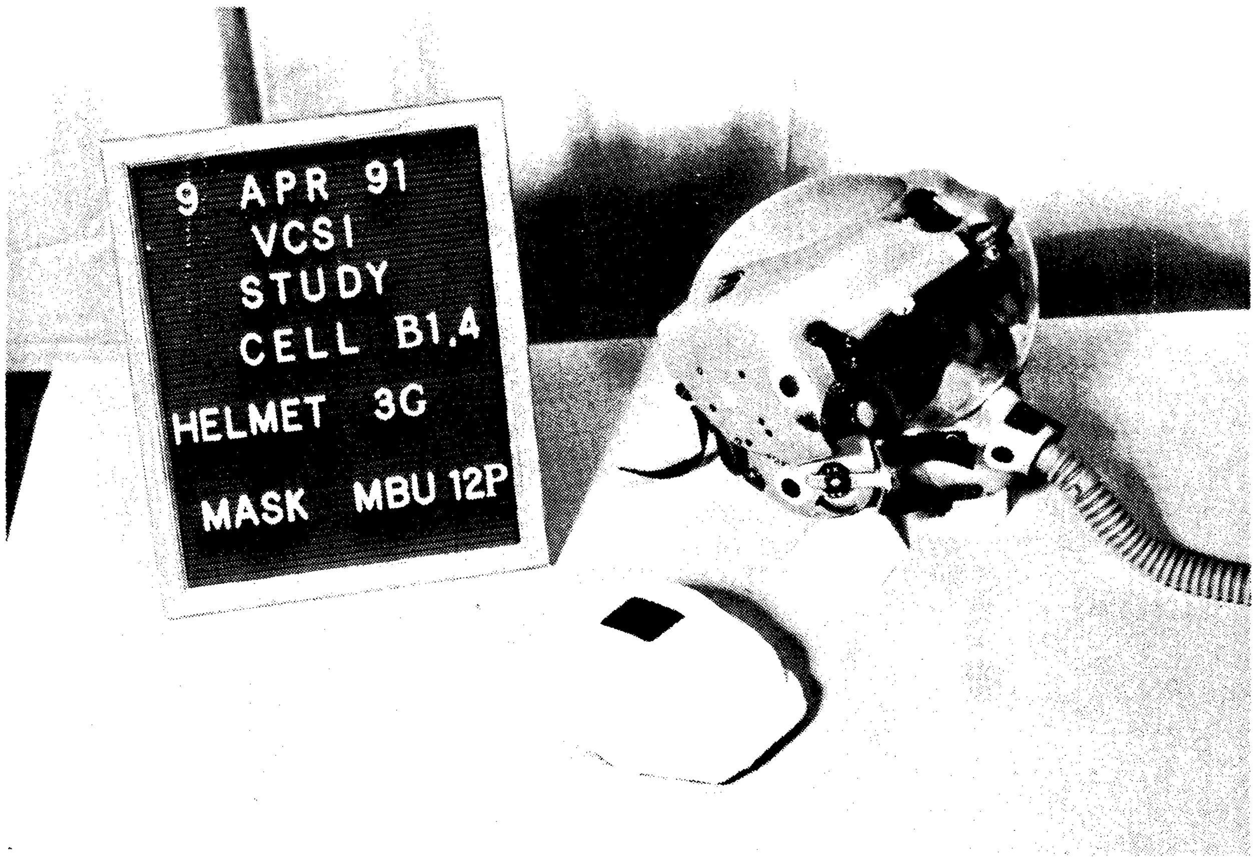



FIGURE A-6: 3G HELMET/MBU-12/P MASK/NIGHT VISION DEVICE COMBINATION


FIGURE A-7: 3H HELMET/MBU-12/P MASK/NIGHT VISION DEVICE COMBINATION

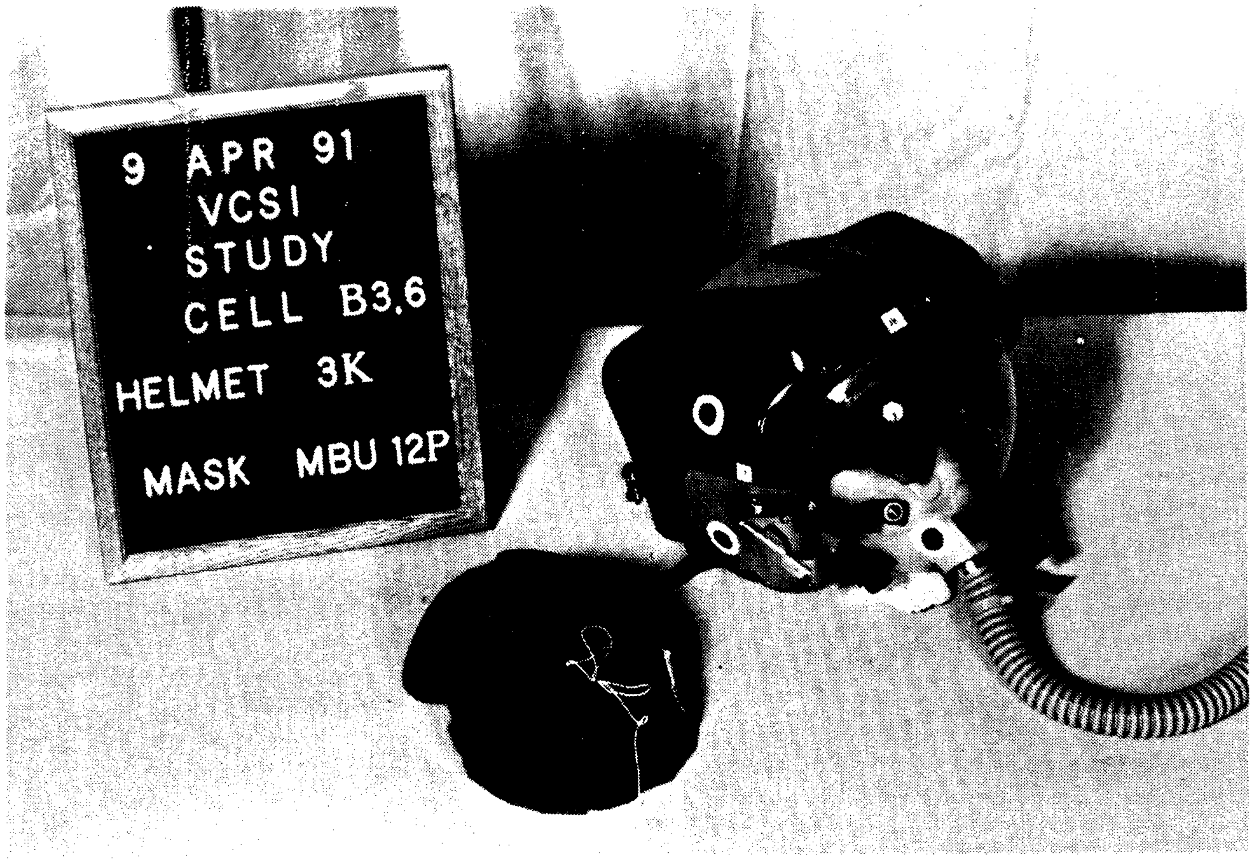
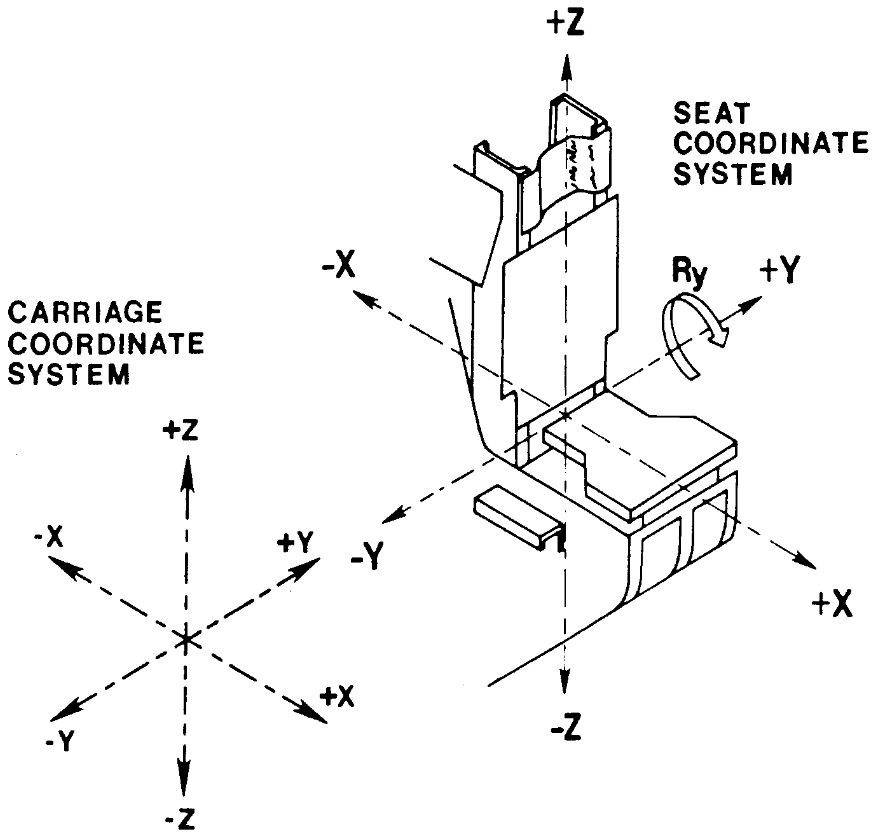



FIGURE A-8: 3K HELMET/MBU-12/P MASK/NIGHT VISION DEVICE COMBINATION



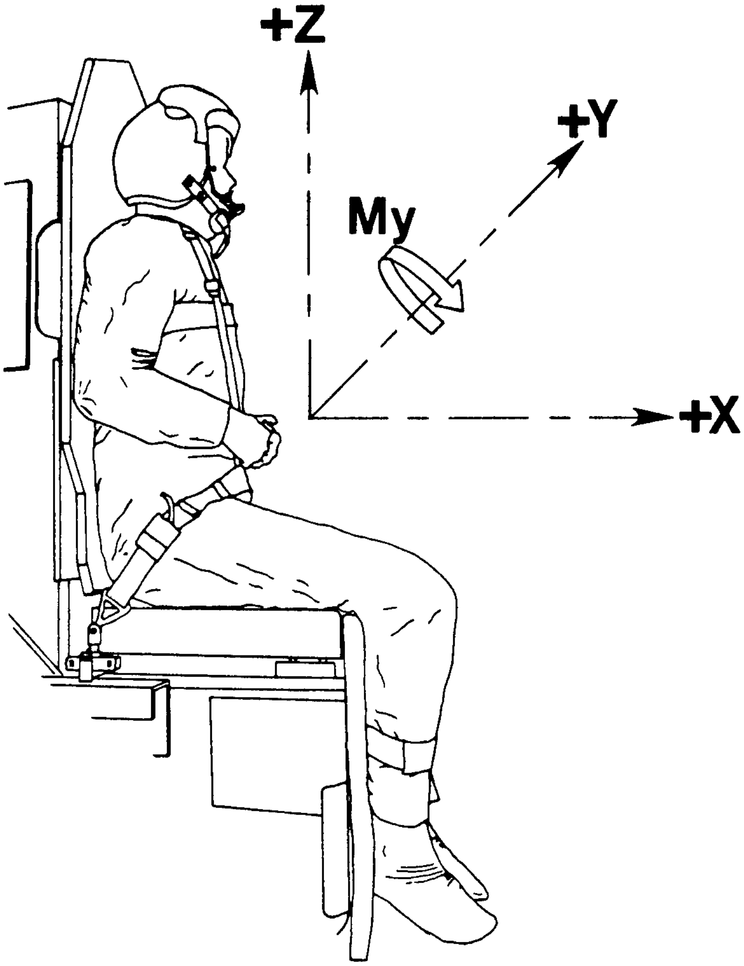

1. ALL TRANSDUCERS EXCEPT THE CARRIAGE ACCELEROMETERS AND THE CARRIAGE VELOCITY TACHOMETER WERE REFERENCED TO THE SEAT COORDINATE SYSTEM. THE CARRIAGE TACHOMETER WAS WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE DURING FREEFALL. THE CARRIAGE ACCELEROMETERS WERE REFERENCED TO THE CARRIAGE COORDINATE SYSTEM.

2. THE LINEAR ACCELEROMETERS WERE WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE WHEN THE ACCELERATION EXPERIENCED BY THE ACCELEROMETER WAS APPLIED IN THE +x, +y OR +z DIRECTION AS SHOWN.

3. THE ANGULAR Ry ACCELEROMETERS WERE WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE WHEN THE ANGULAR ACCELERATION EXPERIENCED BY THE ANGULAR ACCELEROMETER WAS APPLIED IN THE +y DIRECTION ACCORDING TO THE RIGHT HAND RULE AS SHOWN.

4. THE LOAD CELLS AND LOAD LINKS WERE WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE WHEN THE FORCE EXERTED BY THE LOAD CELL ON THE SUBJECT WAS APPLIED IN THE +x, +y OR +z DIRECTION AS SHOWN.

FIGURE A-9: AL/CFBE COORDINATE SYSTEM




1. THE ADAM MANIKIN FORCES AND TORQUES WERE REFERENCED TO THE MANIKIN COORDINATE SYSTEM.

2. THE HEAD AND LUMBAR LOAD CELLS WERE WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE WHEN THE FORCE EXERTED BY THE LOAD CELL, ON THE HEAD OR LUMBAR, WAS APPLIED IN THE +x, +y OR +z DIRECTION AS SHOWN.

3. THE My TORQUE TRANSDUCERS WERE WIRED TO PROVIDE A POSITIVE OUTPUT VOLTAGE WHEN THE TORQUE EXPERIENCED BY THE TRANSDUCERS WAS APPLIED IN THE +y DIRECTION ACCORDING TO THE RIGHT HAND RULE AS SHOWN.

FIGURE A-10: MANIKIN COORDINATE SYSTEM

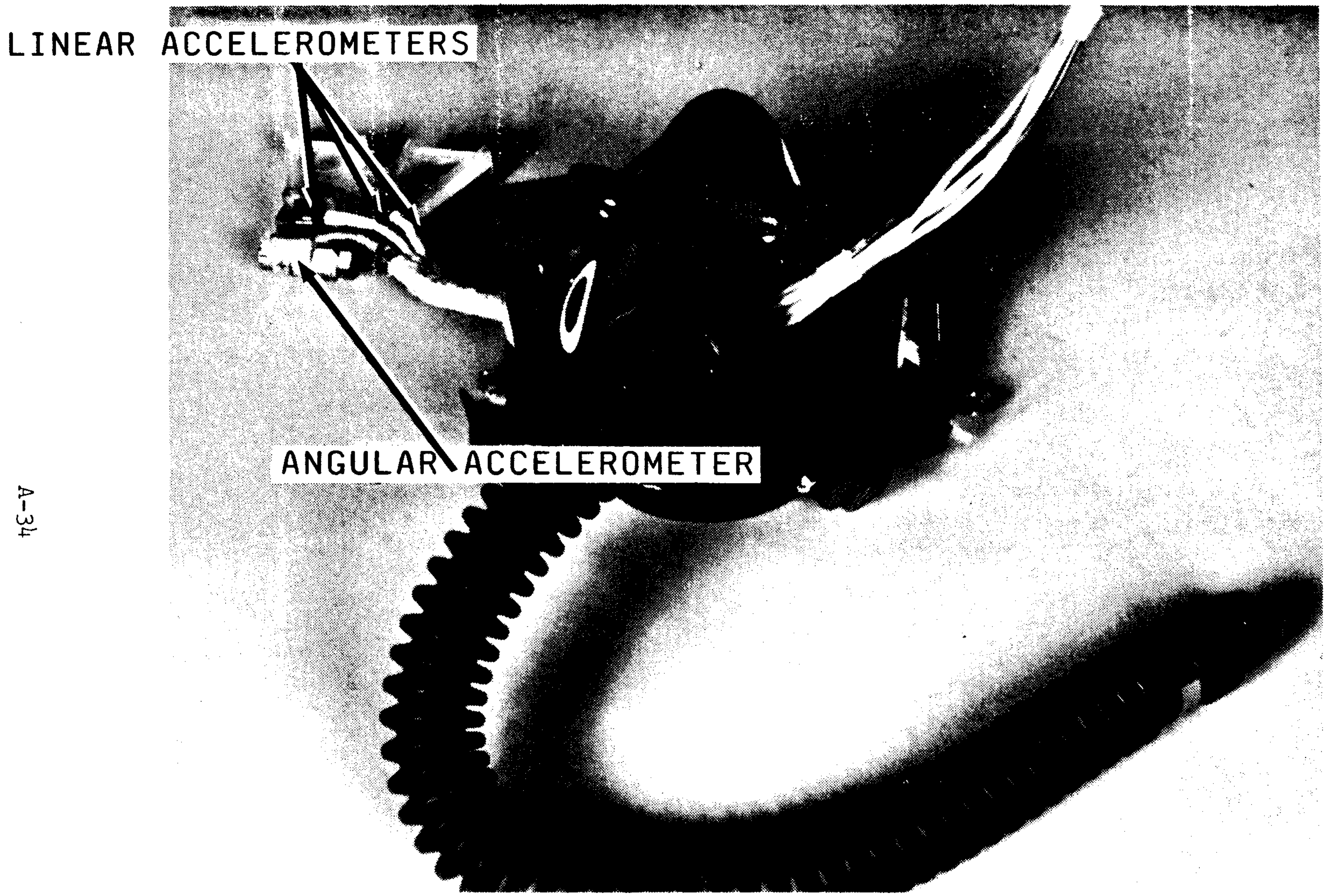



FIGURE A-11: HUMAN HEAD ACCELEROMETER PACKAGE

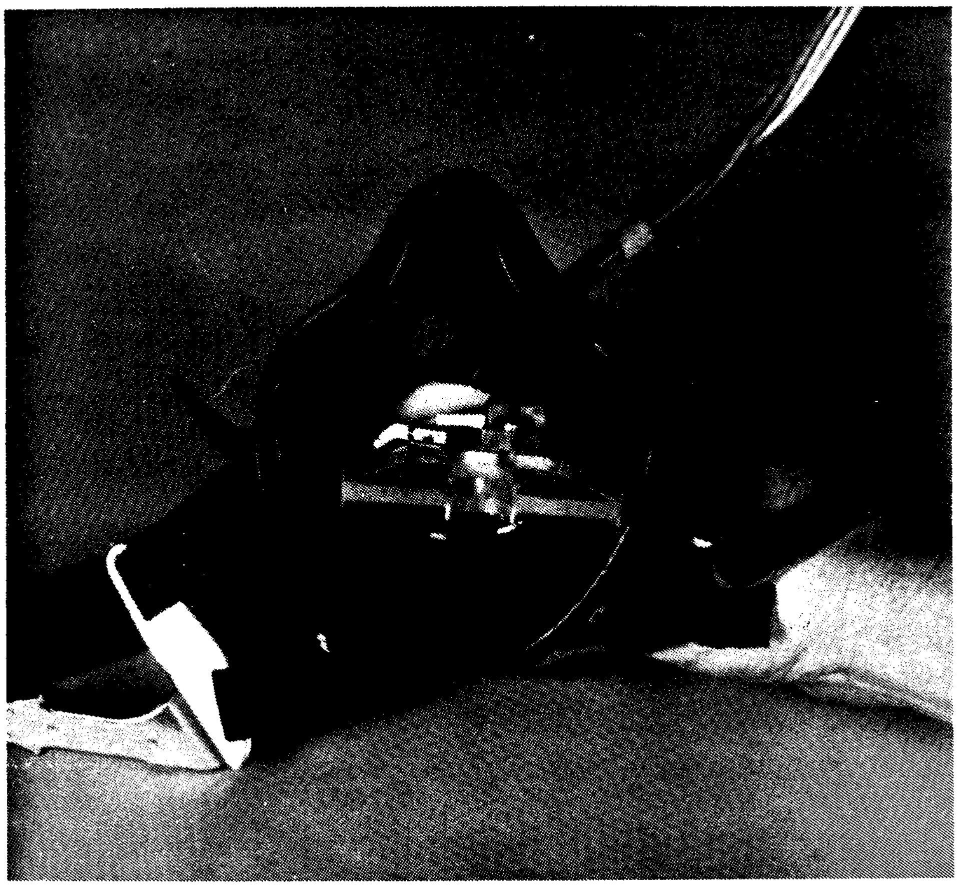


FIGURE A-12: HUMAN HEAD ACCELEROMETER PACKAGE

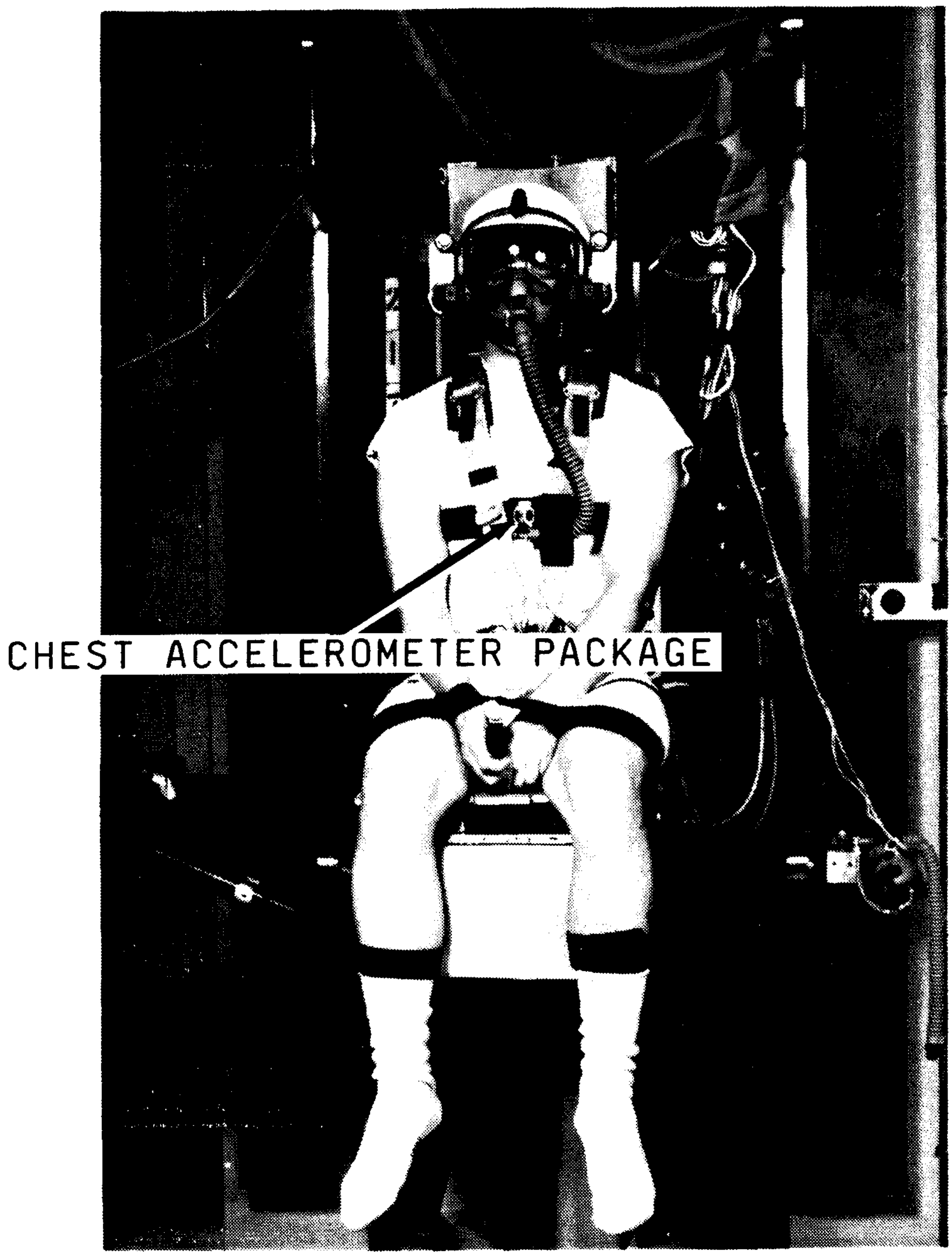
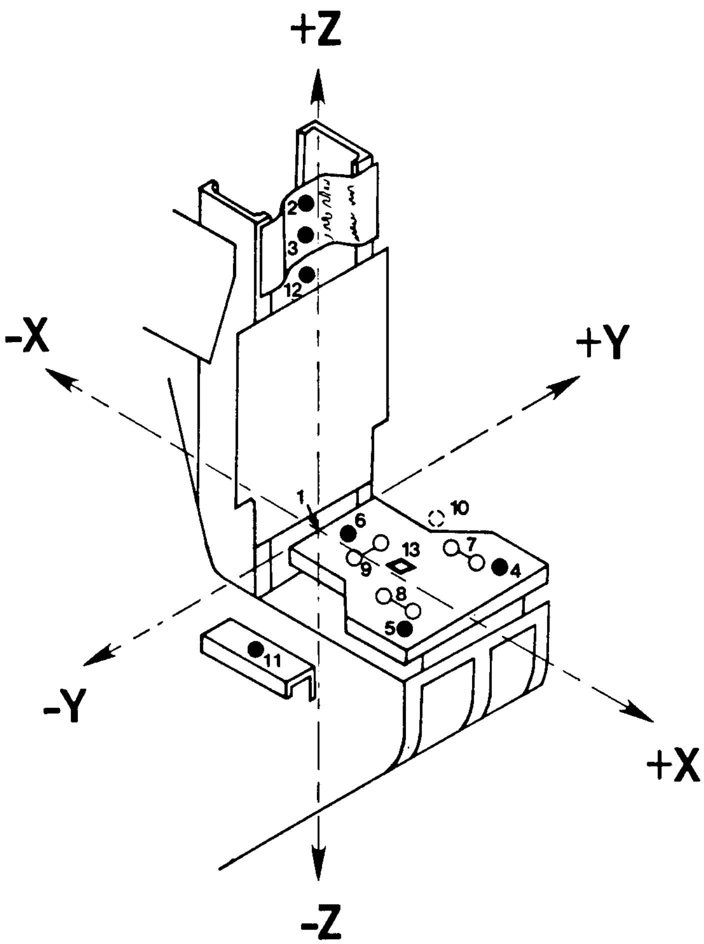



FIGURE A-13: CHEST ACCELEROMETER PACKAGE




| NO. | DESCRIPTION | NO. | DESCRIPTION |
|---|---|---|---|
| 1 | SEAT REFERENCE POINT | 8 | RIGHT SEAT X FORCE |
| 2 | UPPER HEADREST X FORCE | 9 | CENTER SEAT Y FORCE |
| 3 | LOWER HEADREST X FORCE | 10 | LEFT LAP BELT FORCE |
| 4 | LEFT SEAT Z FORCE | 11 | RIGHT LAP BELT FORCE |
| 5 | RIGHT SEAT Z FORCE | 12 | SHOULDER FORCE |
| 6 | CENTER SEAT Z FORCE | 13 | SEAT X, Y & Z ACCELERATION |
| 7 | LEFT SEAT X FORCE | | |

ITEM 10 NOT SHOWN

THE HEADREST WAS ADJUSTABLE UP OR DOWN DEPENDING ON EACH SUBJECT. HEADREST LOAD CELL NUMBERS 2 AND 3 MOVE WITH THE HEADREST. THE MEASUREMENTS FOR THE HEADREST LOAD CELLS WERE TAKEN WHEN THE TOP MOUNTING HOLES IN THE HEAD REST WERE LINED UP WITH THE TOP HOLES IN THE FRAME SUPPORT.

FIGURE A-14a TRANSDUCER LOCATIONS AND DIMENSIONS (PAGE 1 OF 2)

ALL DIMENSIONS ARE REFERENCED TO THE SEAT REFERENCE POINT (SRP). THE SEAT REFERENCE POINT IS LOCATED AT THE INTERSECTION OF THE SEAT PAN CENTER LINE AND THE SEAT BACK CENTER LINE (z AXIS).

CONTACT POINT DIMENSIONS IN INCHES (CM)

| NO. | X | Y | Z |
|---|---|---|---|
| 1 | 0.00 ( 0.00) | 0.00 ( 0.00) | 0.00 ( 0.00) |
| 2 | - 0.31 (- 0.80) | 0.00 ( 0.00) | 37.38 ( 94.95) |
| 3 | - 0.31 (- 0.80) | 0.00 ( 0.00) | 32.47 ( 82.48) |
| 4 | 17.90 ( 45.46) | 5.00 ( 12.70) | - 1.22 (- 3.10) |
| 5 | 17.90 ( 45.46) | - 5.00 (-12.70) | - 1.22 (- 3.10) |
| 6 | 6.68 ( 16.96) | 0.00 ( 0.00) | - 1.22 (- 3.10) |
| 7 | 10.00 ( 25.41) | 6.00 ( 15.25) | - 1.85 (- 4.70) |
| 8 | 10.00 ( 25.41) | - 6.00 (-15.25) | - 1.85 (- 4.70) |
| 9 | 9.26 ( 23.51) | 1.99 ( 5.05) | - 1.85 (- 4.70) |
| 10 | 0.81 ( 2.06) | 9.00 ( 22.86) | - 1.61 (- 4.10) |
| 11 | 0.81 ( 2.06) | - 9.00 (-22.86) | - 1.61 (- 4.10) |
| 12 | - 5.47 (-13.90) | 0.00 ( 0.00) | 27.39 ( 69.58) |
| 13 | 12.33 ( 31.31) | 0.00 ( 0.00) | - 1.69 (- 4.30) |

SEE FIGURE A-14a FOR DESCRIPTIONS OF TRANSDUCER ITEM NUMBERS

THE SEAT ACCELEROMETER MEASUREMENTS (ITEM 13) ARE TAKEN AT THE CENTER OF THE ACCELEROMETER BLOCK.

THE CONTACT POINT IS THE POINT ON THE LOAD CELL AT WHICH THE EXTERNAL FORCE IS APPLIED.

THE MEASUREMENTS FOR THE LOAD CELLS WHICH ANCHOR THE HARNESS (ITEMS 10, 11 & 12) ARE TAKEN AT THE POINT WHERE THE HARNESS IS ATTACHED TO THE LOAD CELL.

FIGURE A-14b: TRANSDUCER LOCATIONS AND DIMENSIONS (PAGE 2 OF 2)

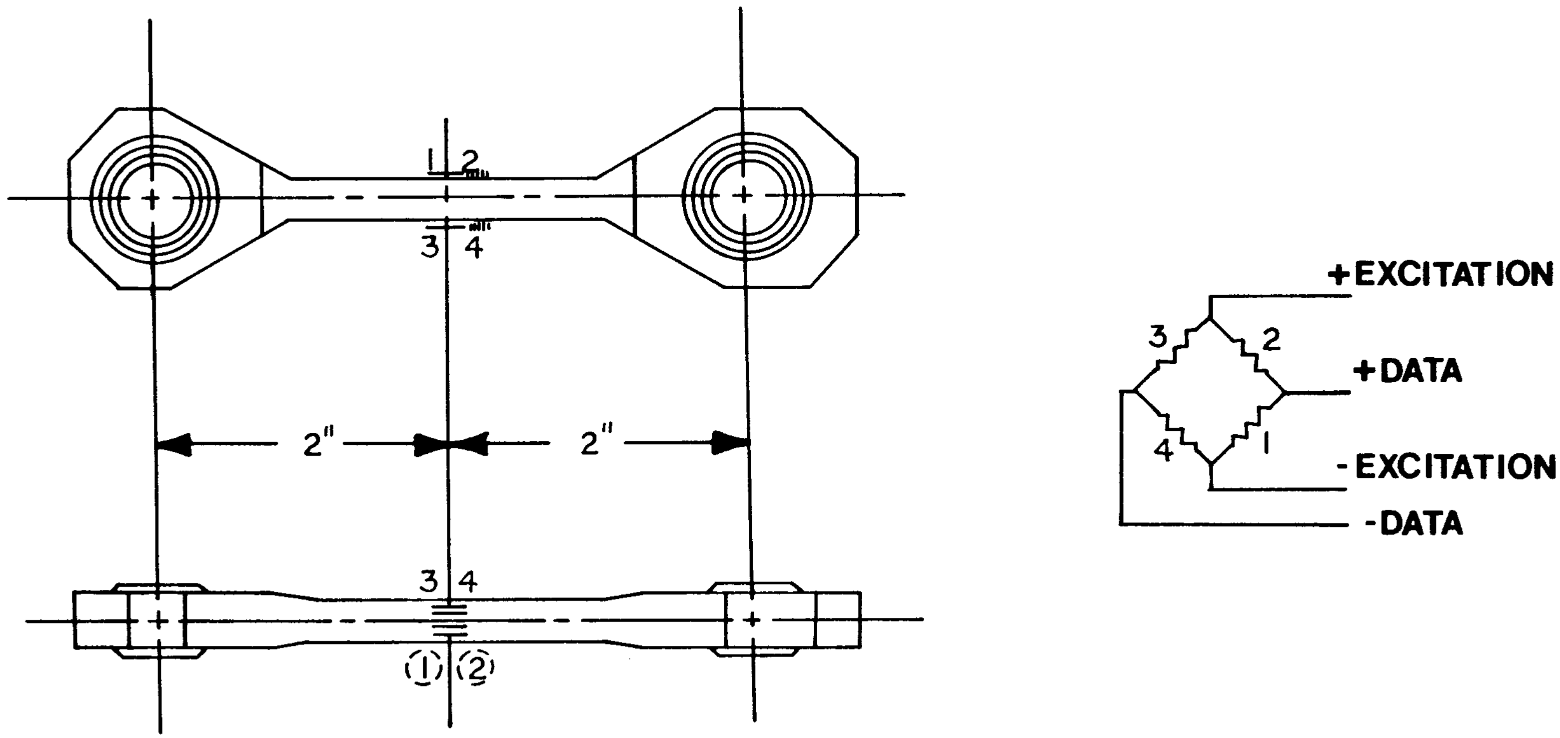
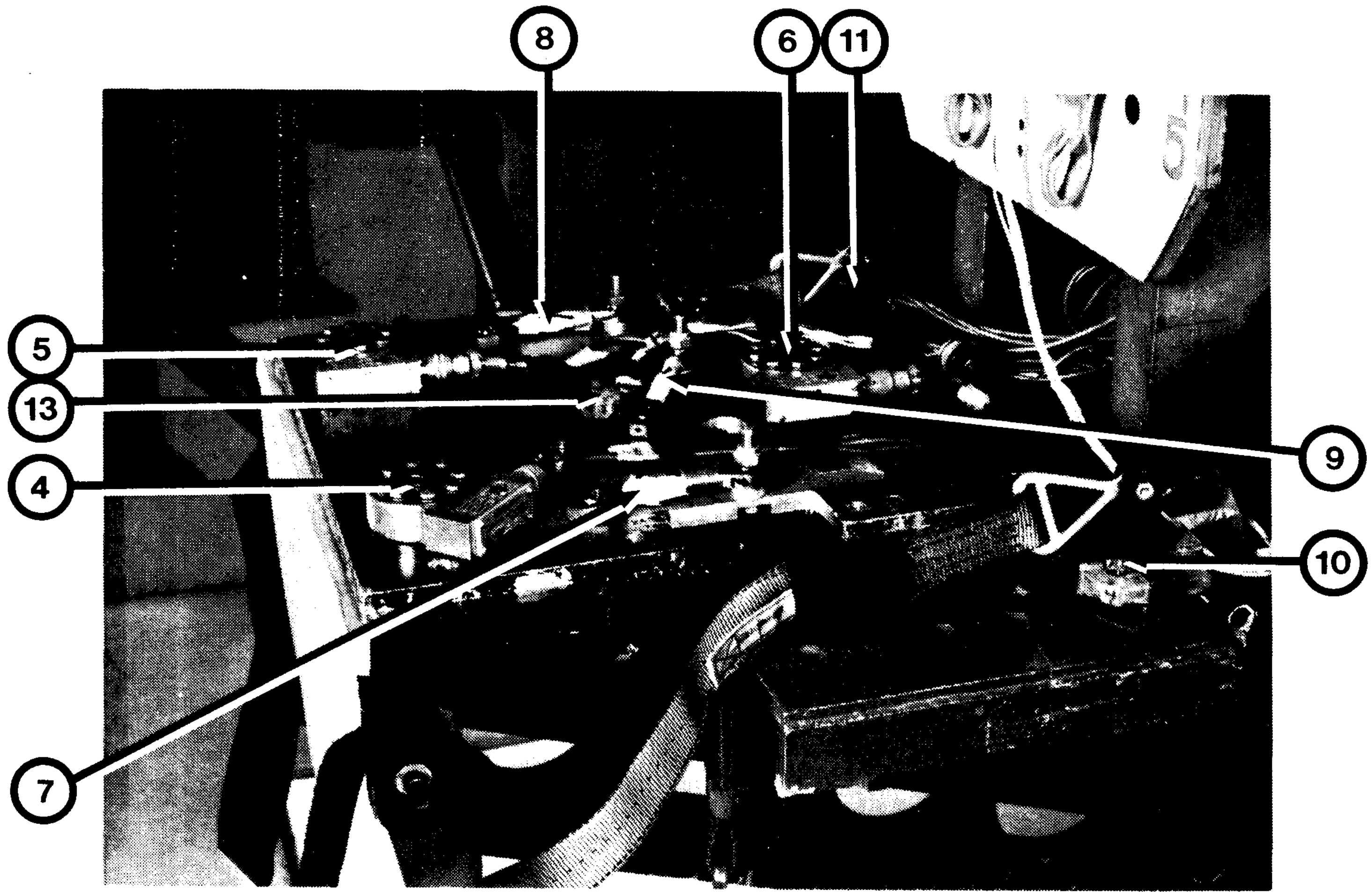
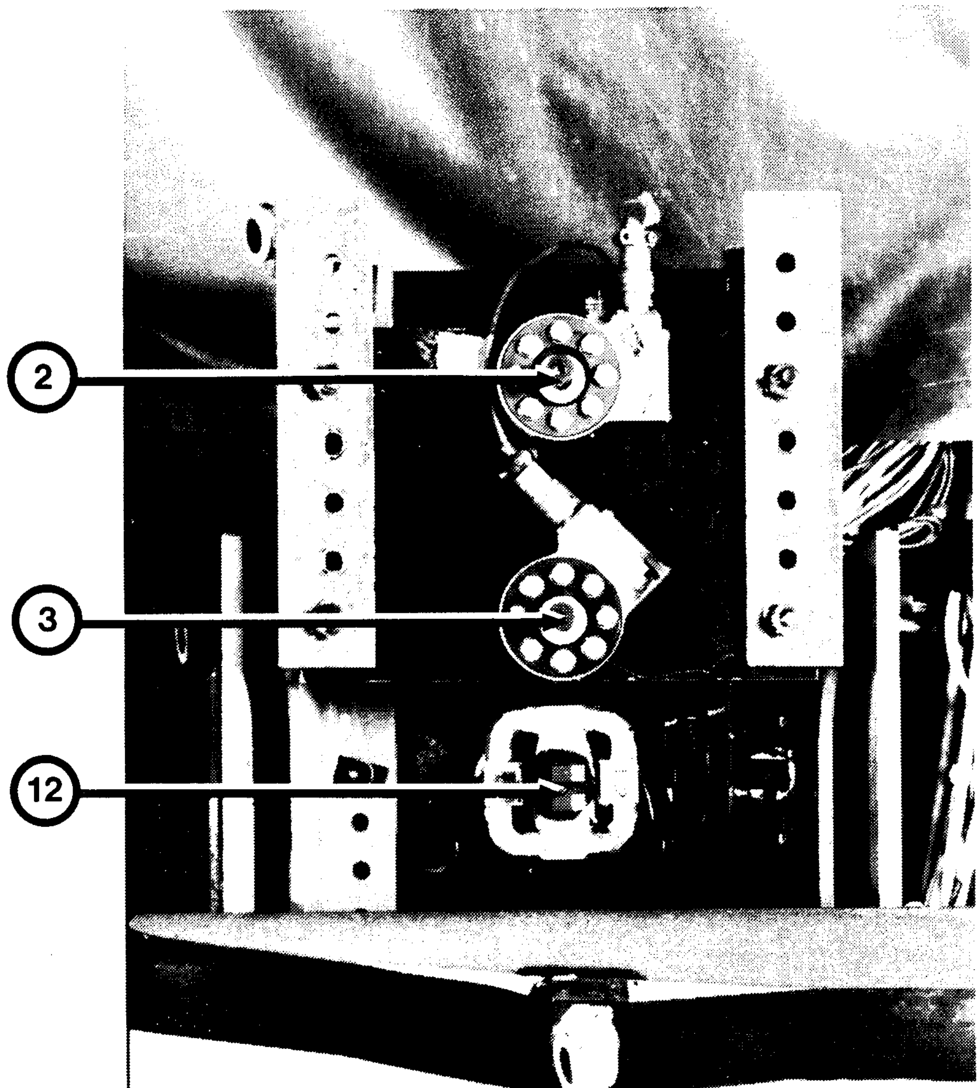



FIGURE A-15: LOAD LINK INSTRUMENTATION




NOTE: REFER TO FIGURE A-14a FOR A DESCRIPTION OF THE TRANSDUCER ITEM NUMBERS.

FIGURE A-16: SEAT PAN INSTRUMENTATION




NOTE: REFER TO FIGURE A-14a FOR A DESCRIPTION OF THE TRANSDUCER ITEM NUMBERS.

FIGURE A-17: HEADREST AND SHOULDER LOAD CELL INSTRUMENTATION

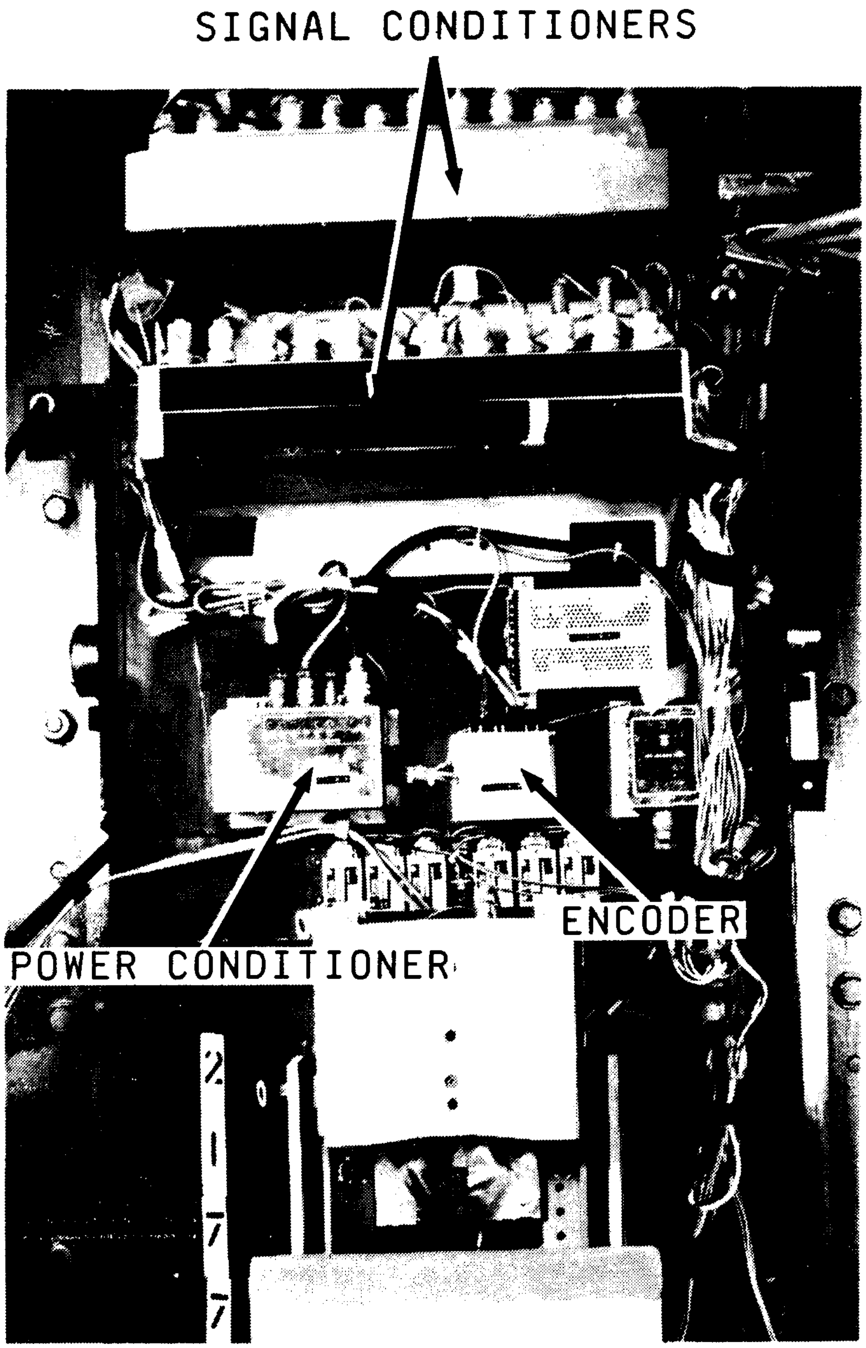



FIGURE A-18: ADACS INSTALLATION

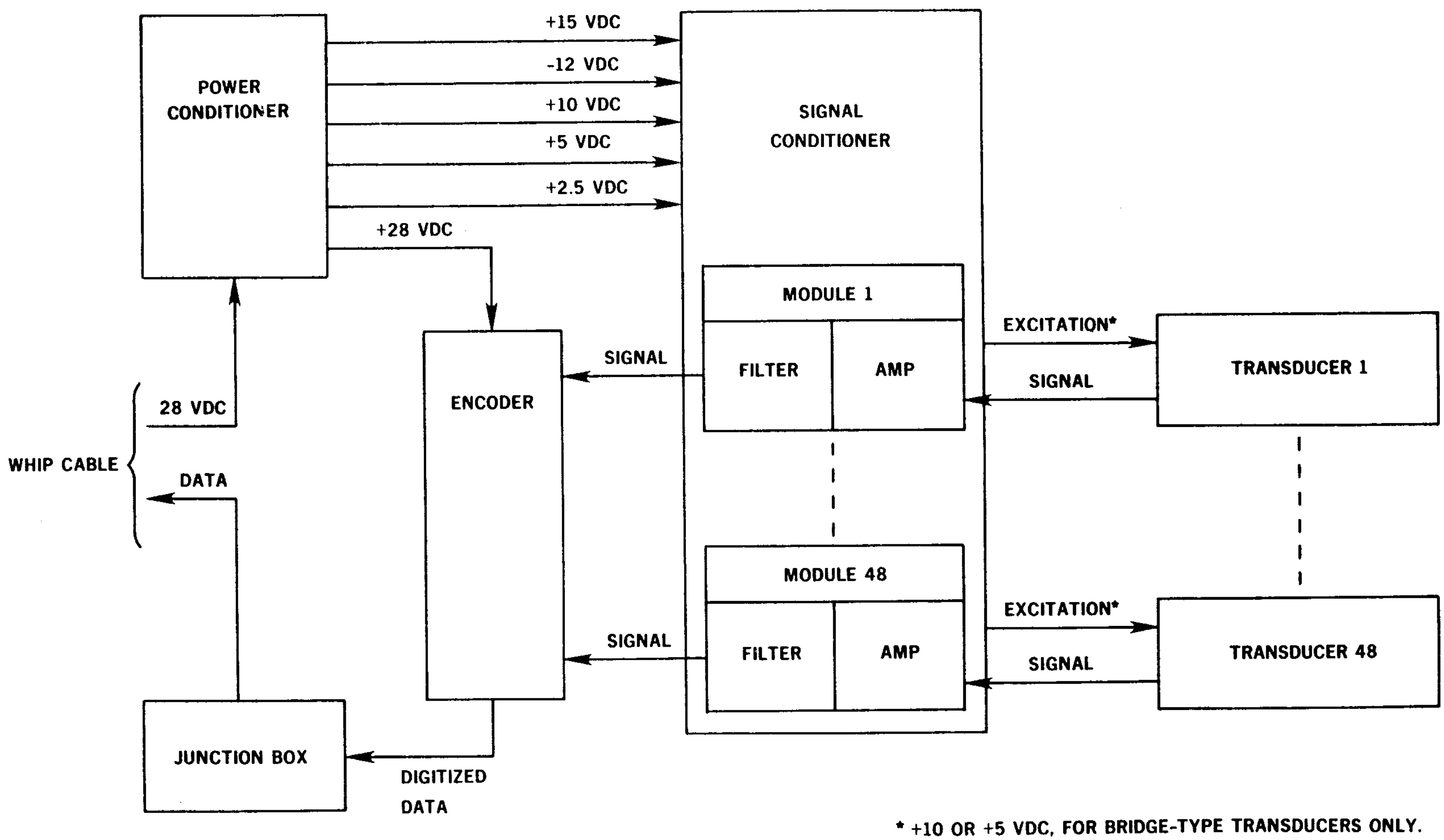



FIGURE A-19: AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM

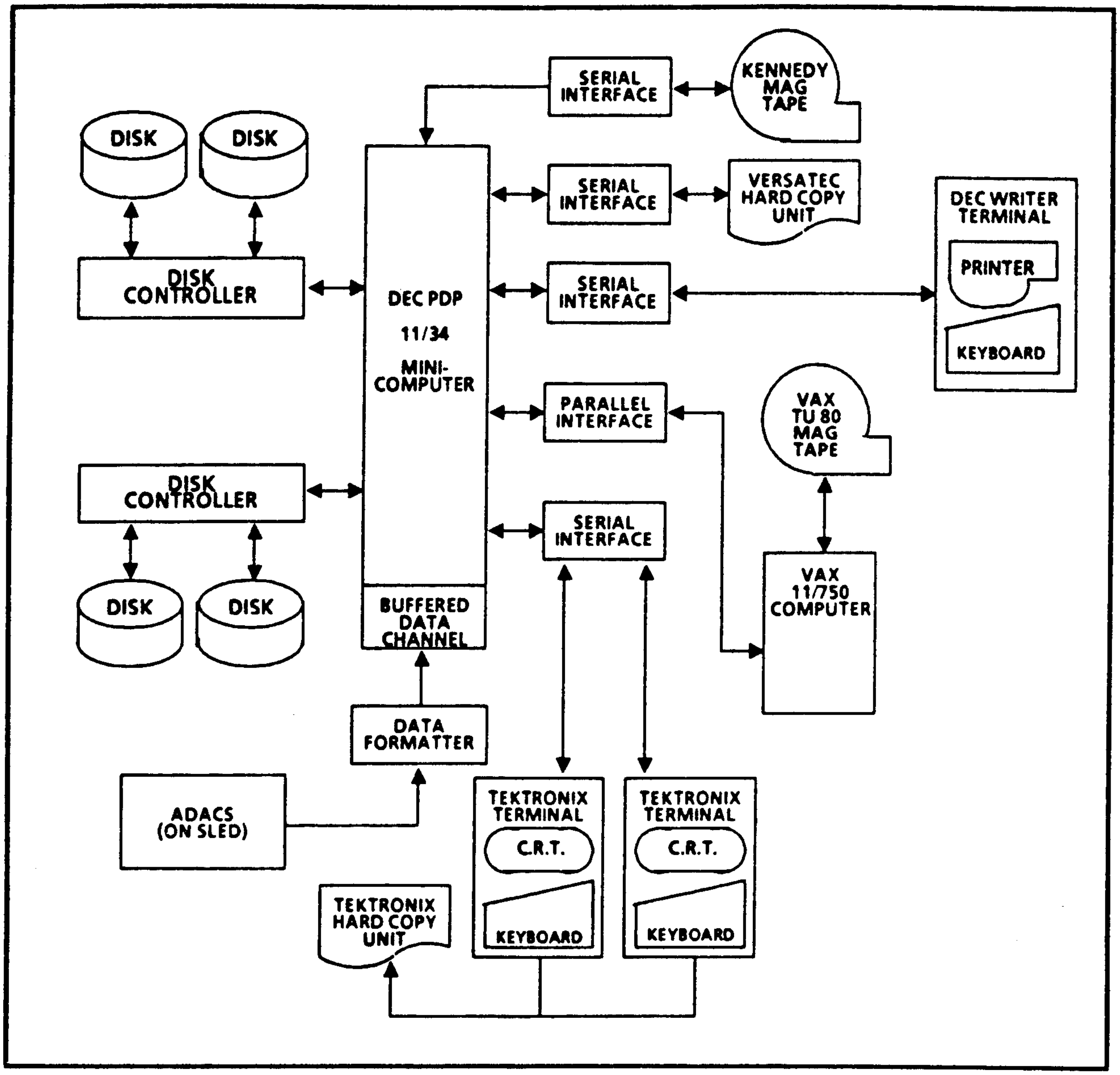



FIGURE A-20: DATA ACQUISITION AND STORAGE SYSTEM BLOCK DIAGRAM

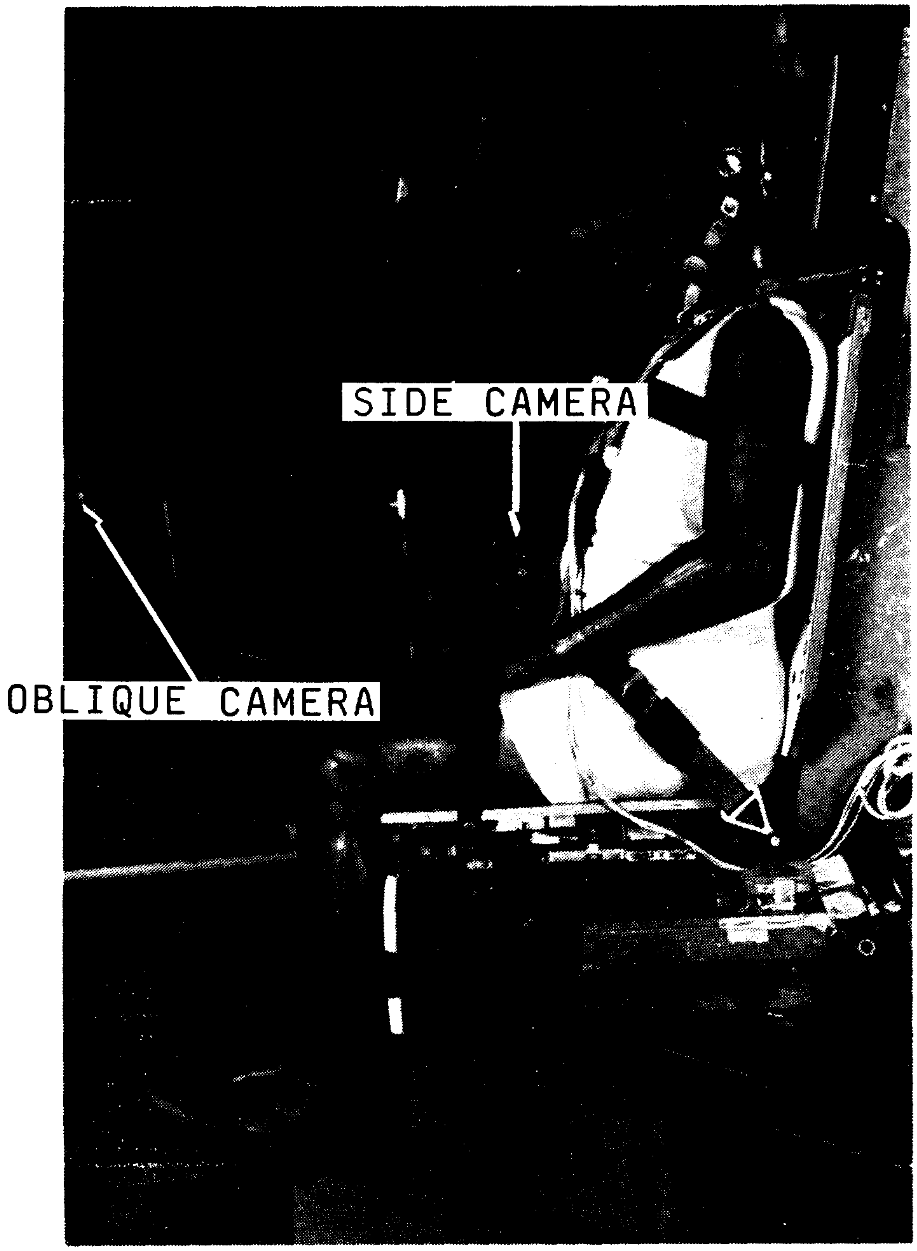
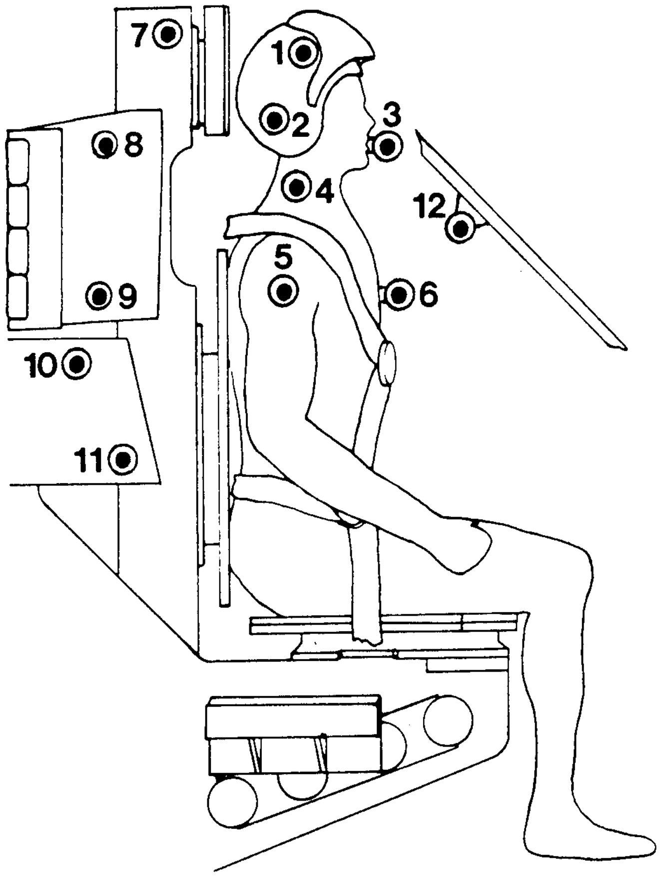



FIGURE A-21: ONBOARD CAMERA LOCATIONS




ALL DIMENSIONS ARE REFERENCED TO THE SEAT REFERENCE POINT (SRP). THE SEAT REFERENCE POINT IS LOCATED AT THE INTERSECTION OF THE SEAT PAN CENTER LINE AND THE SEAT BACK CENTER LINE (z AXIS).

| | DESCRIPTION | DIMENSIONS IN FEET | | |
|---|---|---|---|---|
| | | x | y | z |
| 1. | UPPER HELMET | - | - | - |
| 2. | LOWER HELMET | - | - | - |
| 3. | MASK | - | - | - |
| 4. | NECK | - | - | - |
| 5. | SHOULDER | - | - | - |
| 6. | CHEST | - | - | - |
| 7. | UPPER FRAME | -0.1411 | -0.5399 | +3.3953 |
| 8. | UPPER NUMBER PLATE | -0.7979 | -0.7887 | +2.6854 |
| 9. | LOWER NUMBER PLATE | -0.8225 | -0.7904 | +1.8163 |
| 10. | CENTER FRAME | -0.6312 | -0.6337 | +1.4196 |
| 11. | LOWER CENTER FRAME | -0.3632 | -0.6616 | +0.8258 |
| 12. | CAMERA STRUT | +2.0518 | -2.4725 | +2.3162 |

FIGURE A-22: FIDUCIAL TARGET LOCATIONS

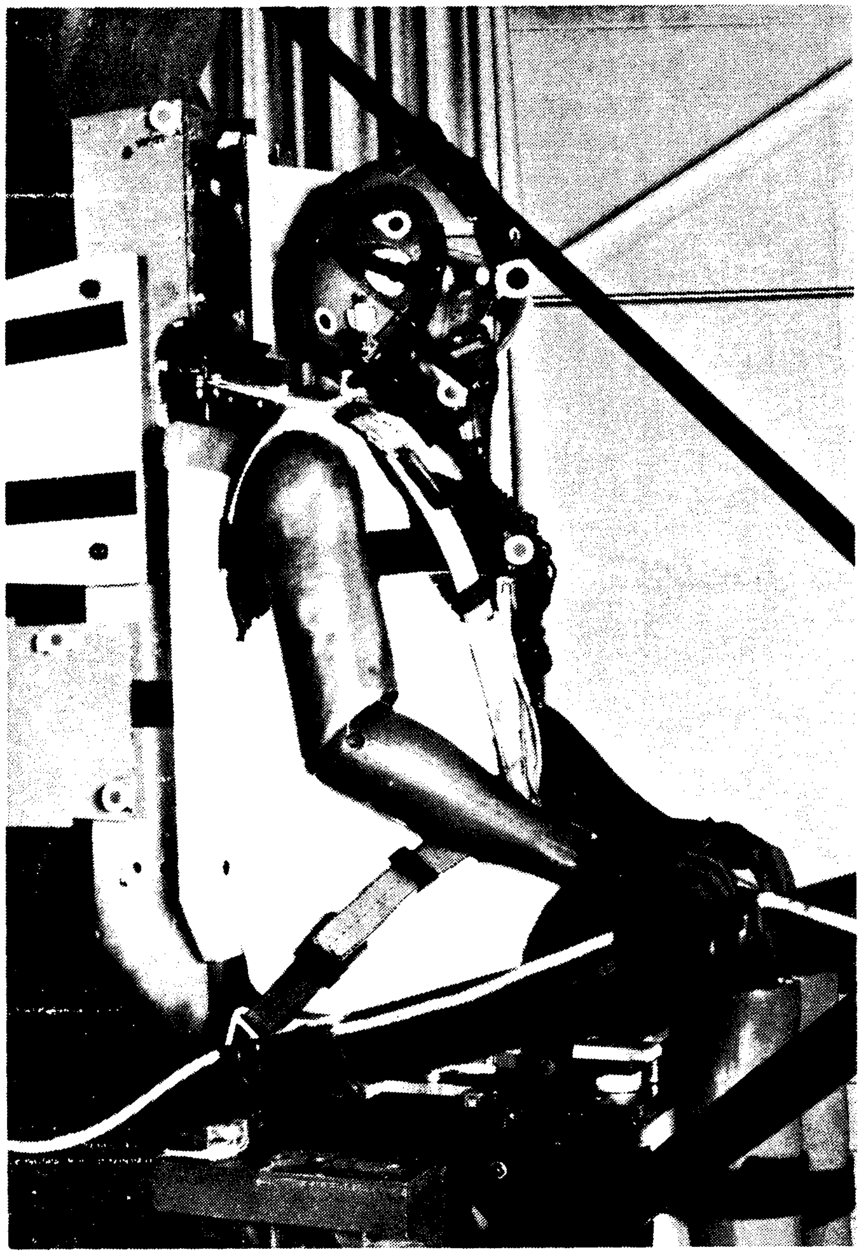


FIGURE A-23: FIDUCIAL TARGETS

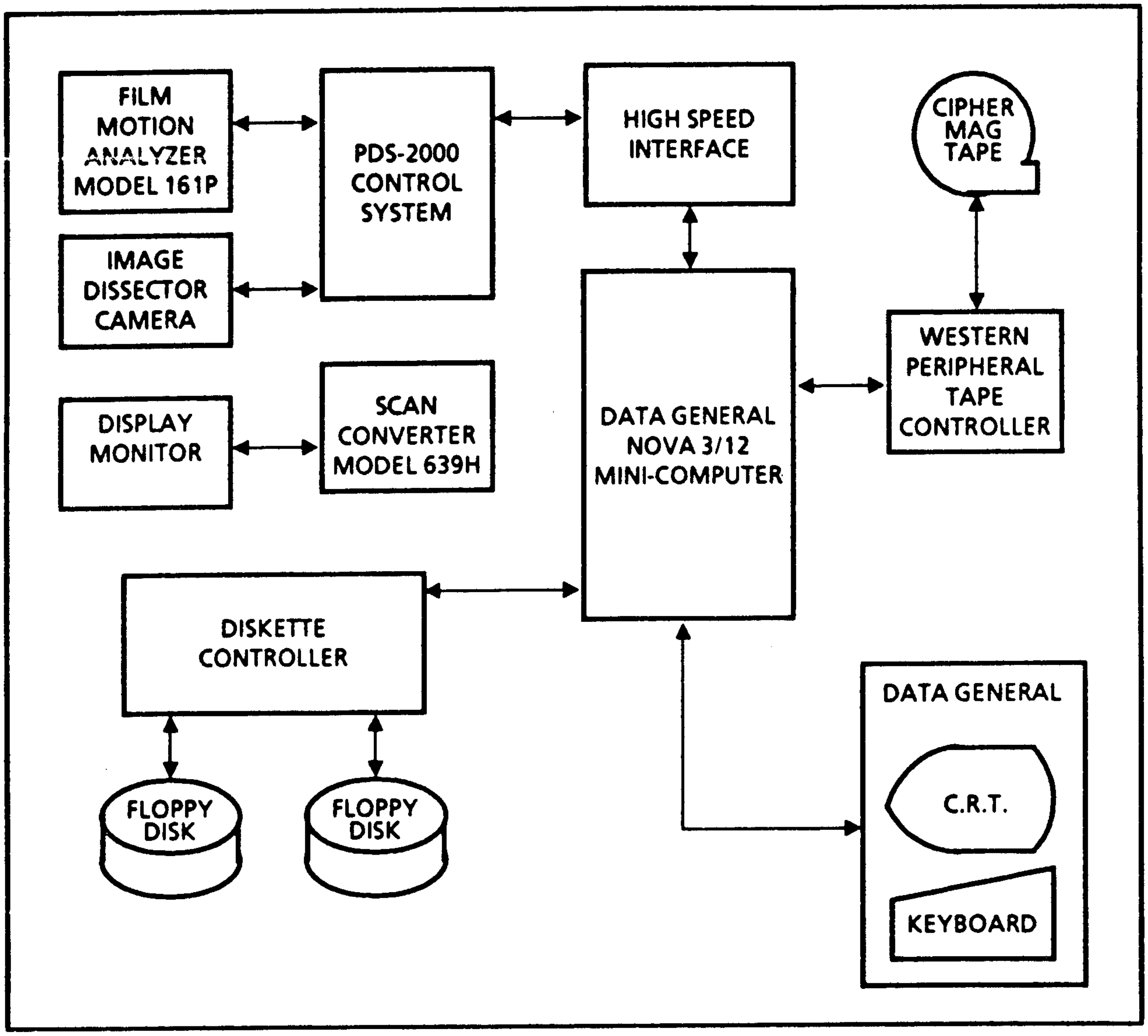



FIGURE A-24: AUTOMATIC FILM READER

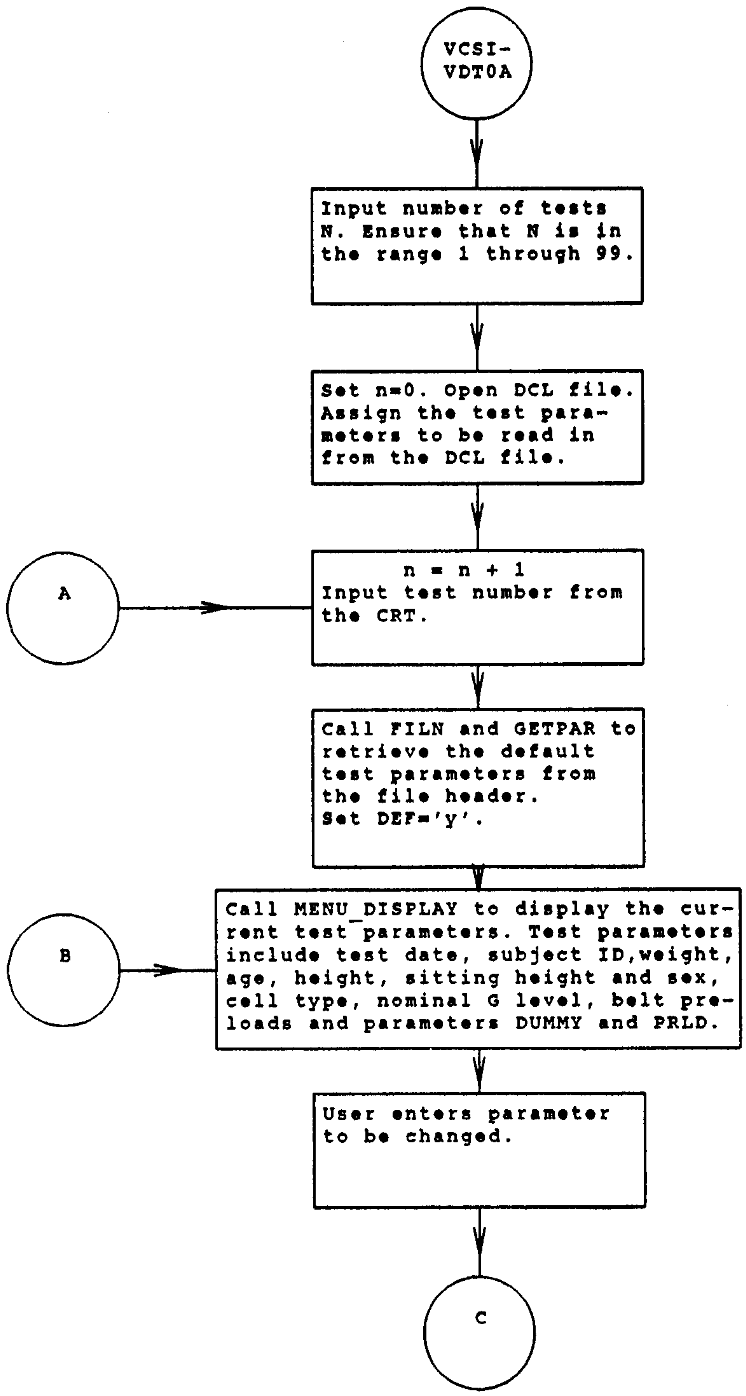



FIGURE A-25a: PROGRAM VCSIVDTØA FLOWCHART (PAGE 1 OF 3)

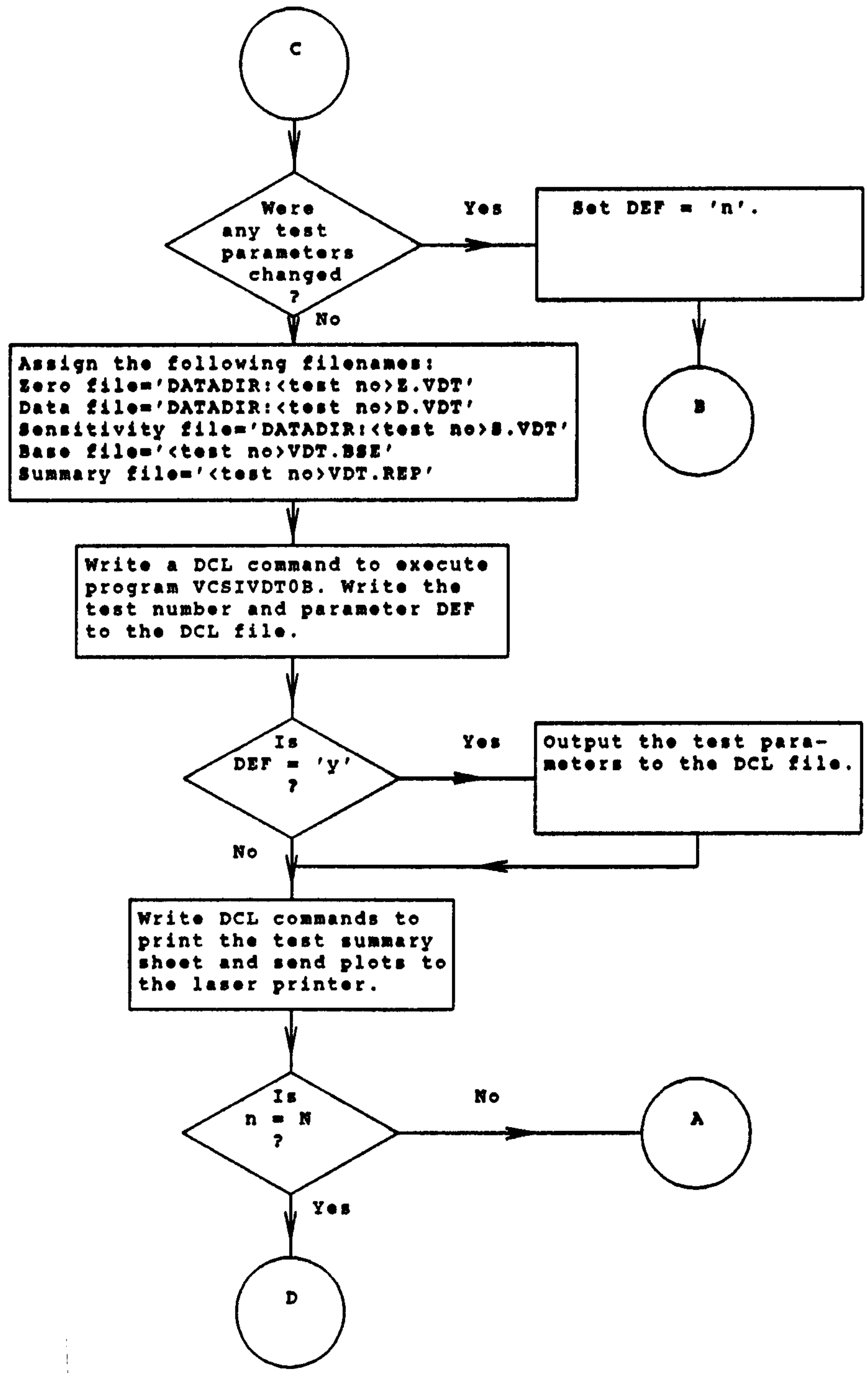



FIGURE A-25b: PROGRAM VCSIVDTØA FLOWCHART (PAGE 2 OF 3)

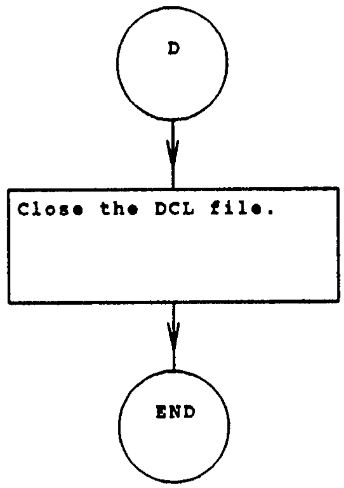



FIGURE A-25c: PROGRAM VCSIVDTØA FLOWCHART (PAGE 3 OF 3)

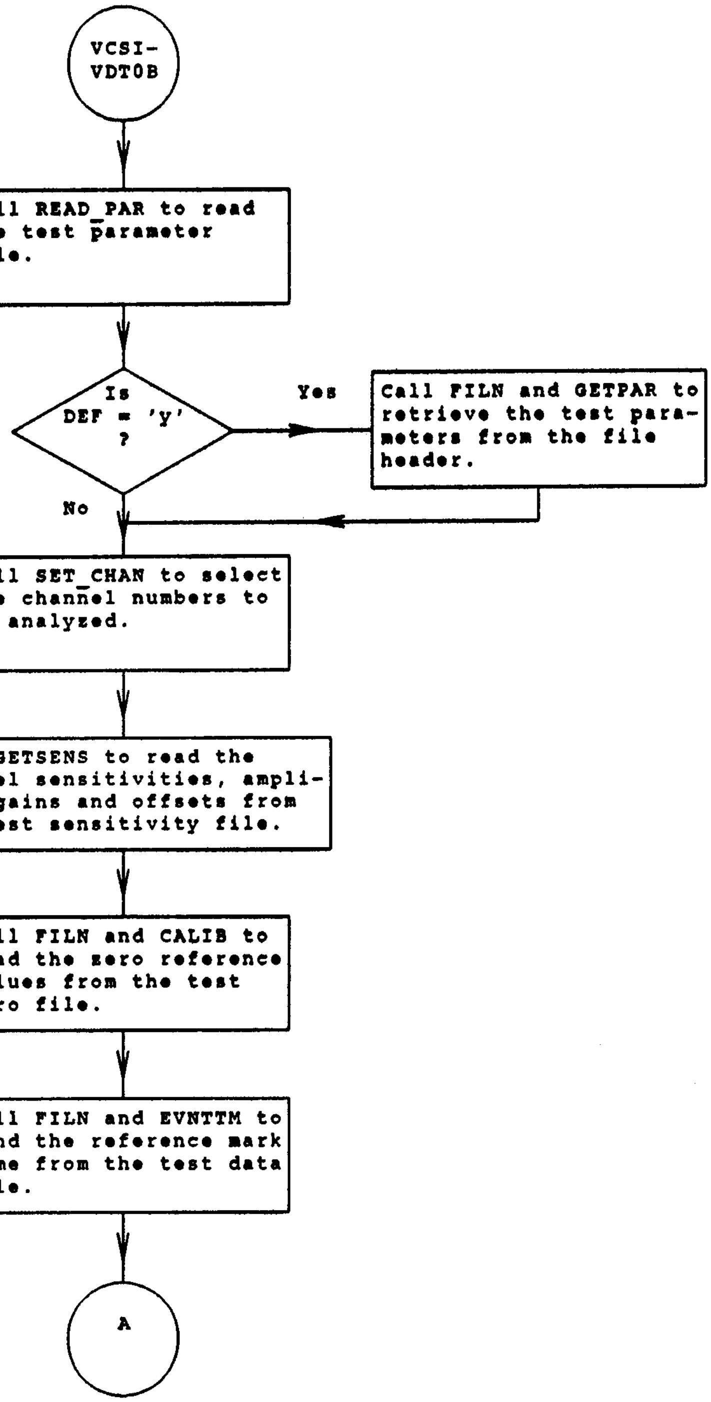



FIGURE A-26a: PROGRAM VCSIVDTØB FLOWCHART (PAGE 1 OF 8)

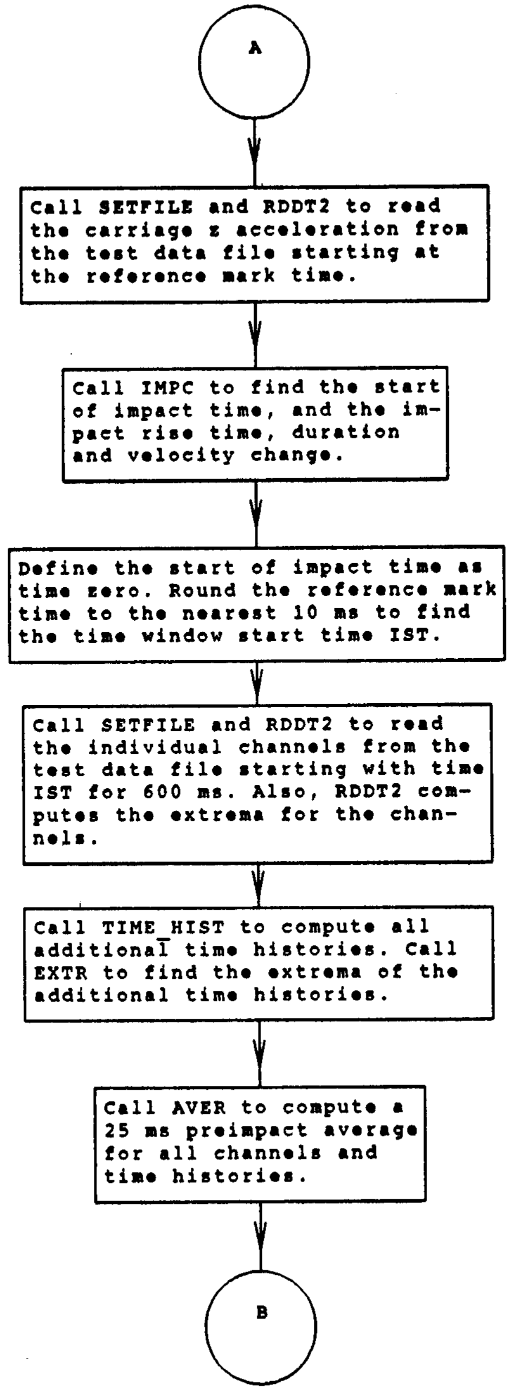



FIGURE A-26b: PROGRAM VCSIVDTØB FLOWCHART (PAGE 2 OF 8)

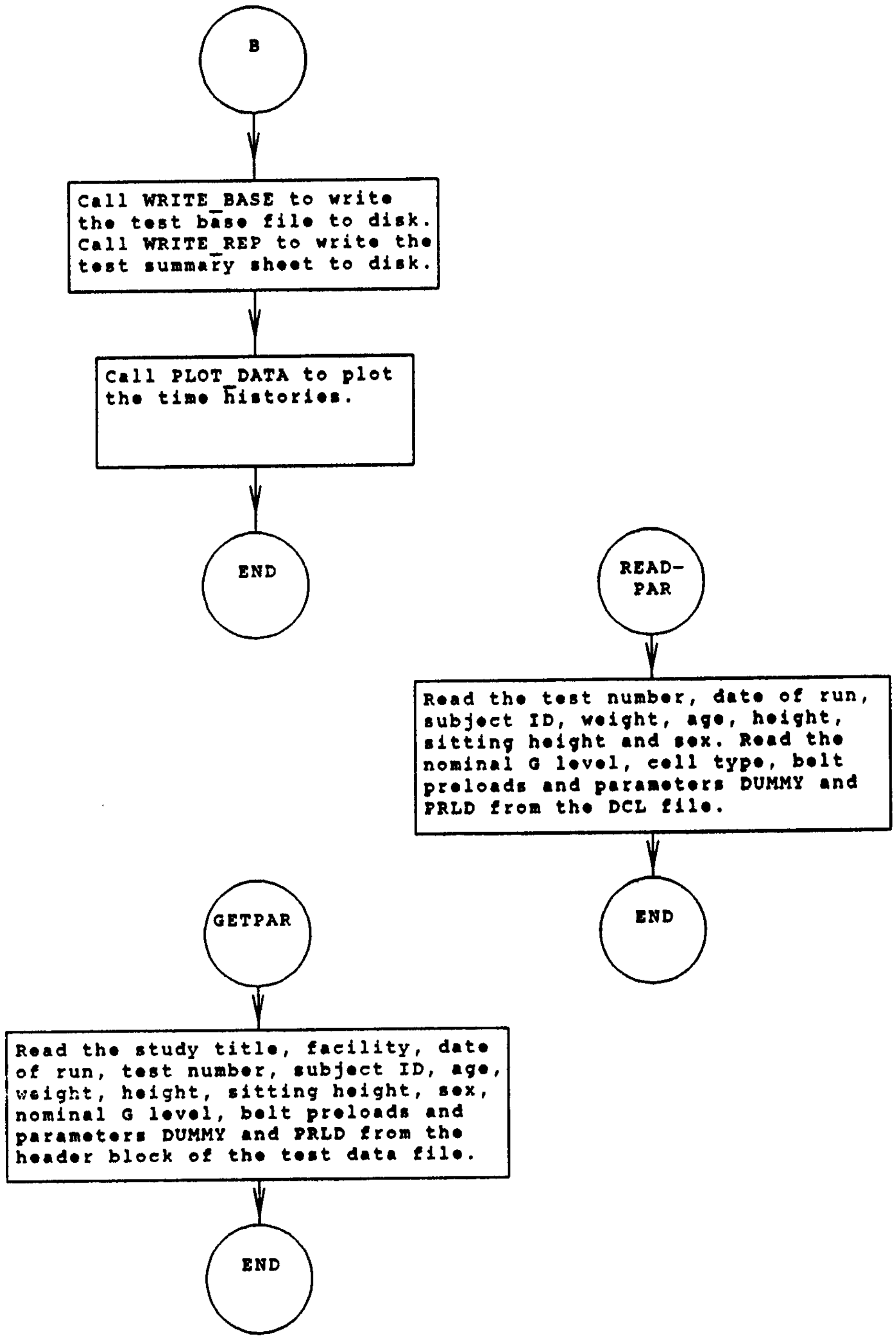



FIGURE A-26c: PROGRAM VCSIVDTØB FLOWCHART (PAGE 3 OF 8)

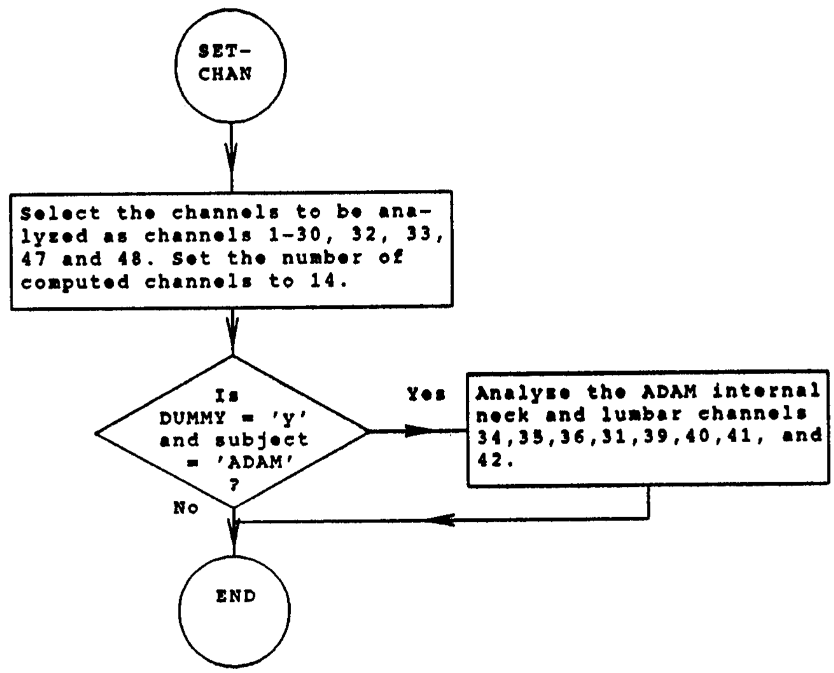



FIGURE A-26d: PROGRAM VCSIVDTØB FLOWCHART (PAGE 4 OF 8)

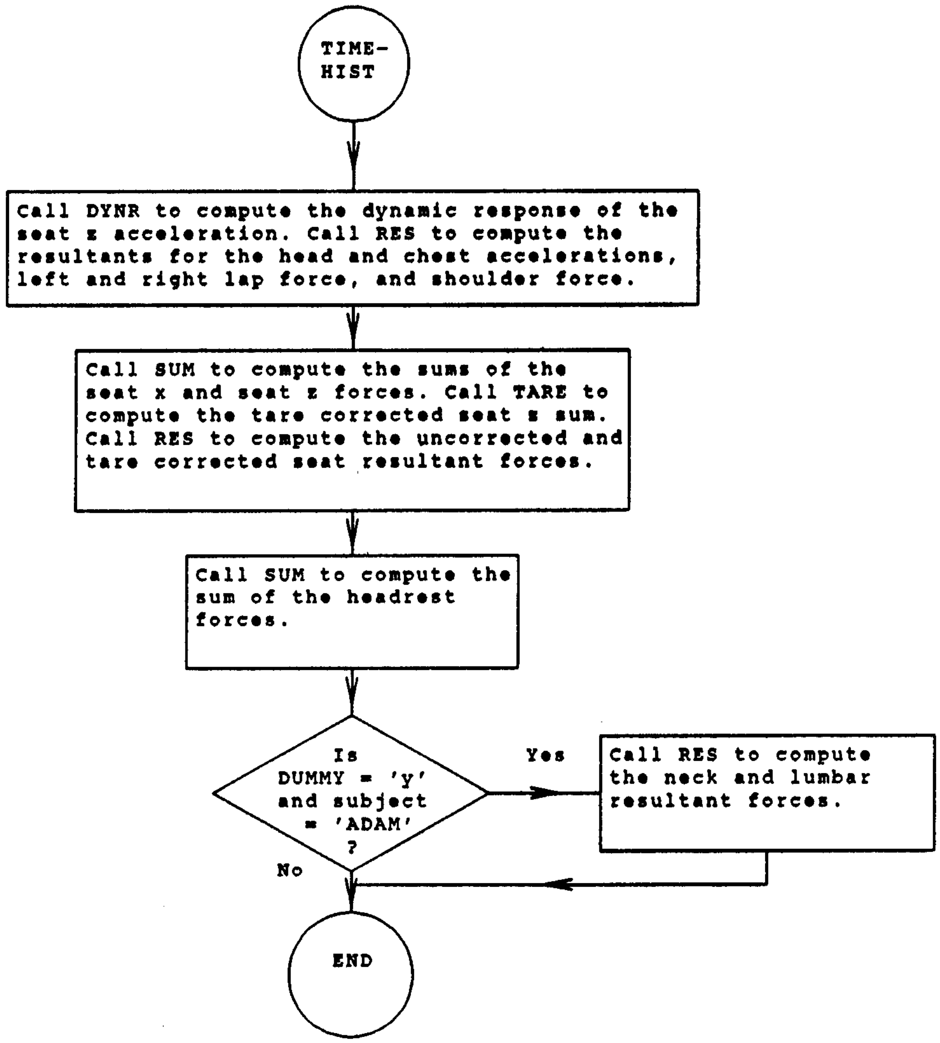



FIGURE A-26e: PROGRAM VCSIVDTØB FLOWCHART (PAGE 5 OF 8)

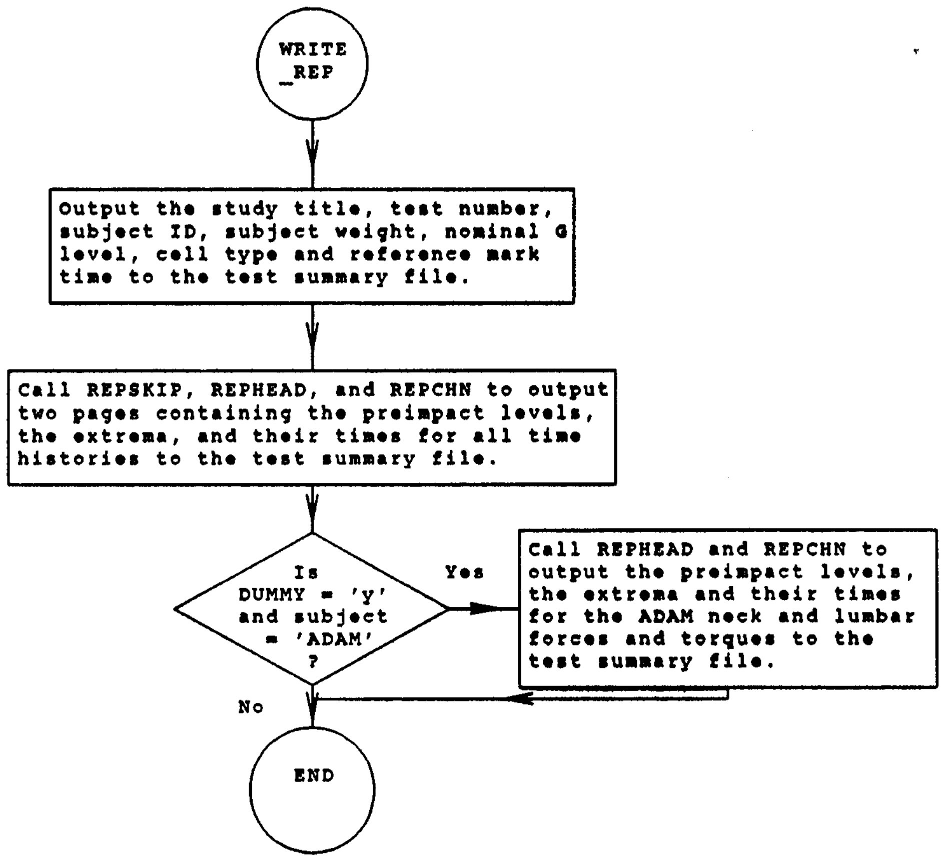



FIGURE A-26f: PROGRAM VCSIVDTØB FLOWCHART (PAGE 6 OF 8)

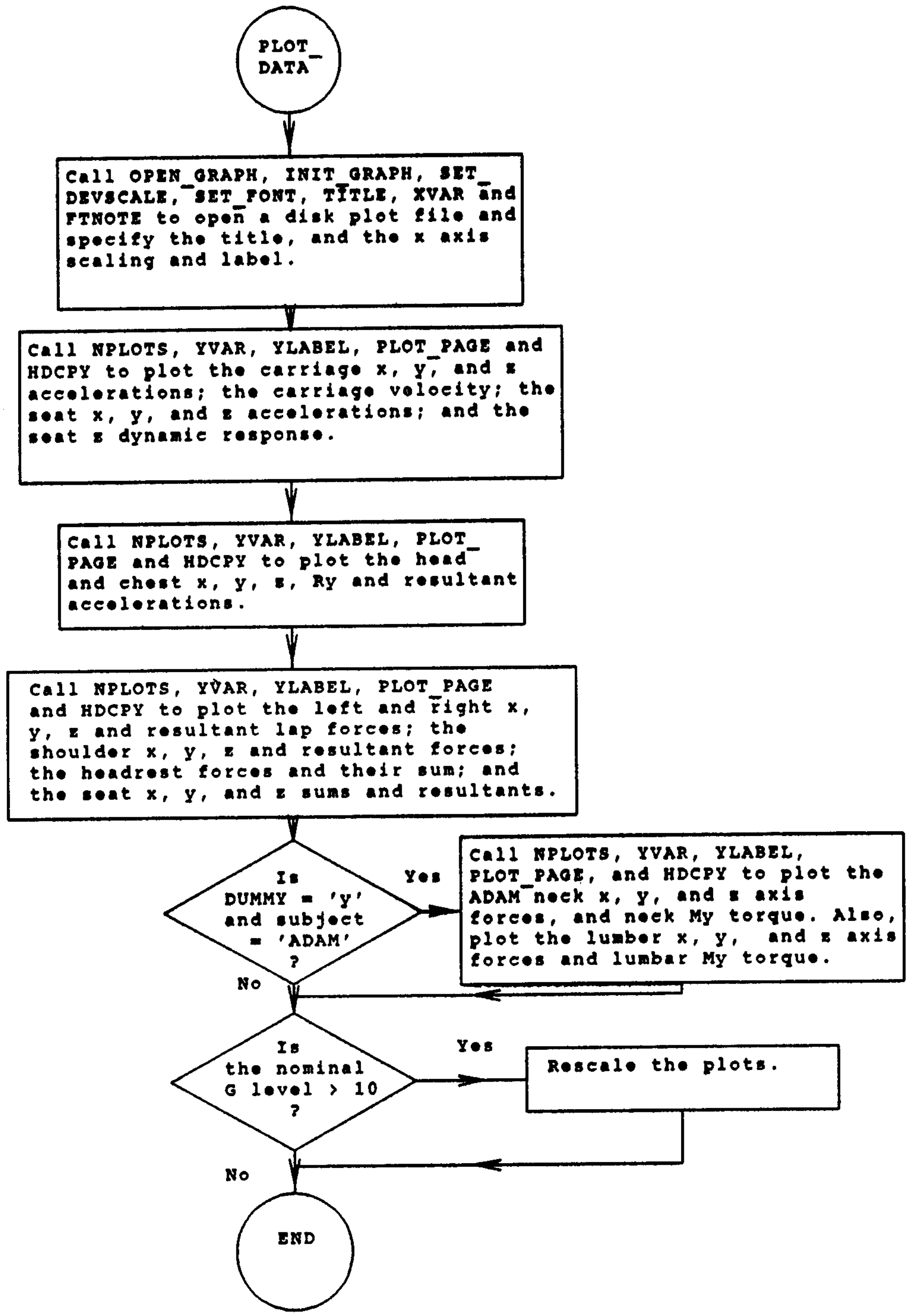



FIGURE A-26g: PROGRAM VCSIVDTØB FLOWCHART (PAGE 7 OF 8)

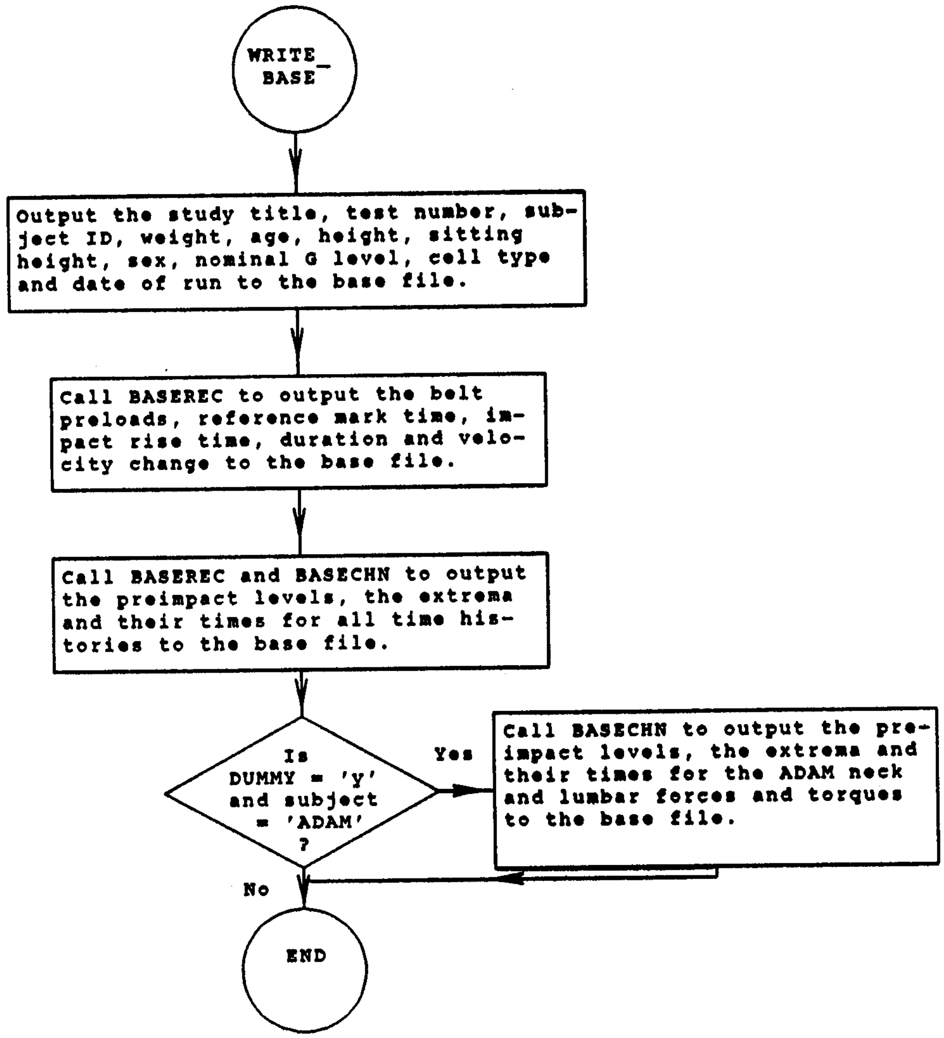



FIGURE A-26h: PROGRAM VCSIVDTØB FLOWCHART (PAGE 8 OF 8)



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